AIRCRAFT TEMPLATE DEVELOPMENT

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Under Supervision of Staff Engineer
ERNEST J. GENTLE

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PREFACE

This book on template development for aircraft has been compiled and published to achieve two main objectives: (1) To enable students to learn in the shortest possible time all of the basic principles involved in the developing and making of aircraft templates; (2) To aid aircraft factories materially in solving their skilled personnel problems, by providing for students, apprentices and trainees a basic and authoritative technical text that will give the students exactly the type of practical training that will be of most value to the factories.

In these days of modern mass-production there is a constant daily use of an ever-increasing number of aircraft templates which has become an imperative necessity both for interchangeability and for reduced production costs.

This new and sorely needed book contains a copiously illustrated, complete and comprehensive description of the art and science of making aircraft templates the way the manufacturer wants and must have them. It presents all of the fundamental principles involved. By combining these principles with the proper classroom instruction and practical technical shop experience, the earnest student will gain an understanding which should enable him to develop practically any type of aircraft template with a minimum amount of further guidance or assistance.

Aero Publishers gratefully acknowledge the assistance and collaboration of all individuals and aircraft manufacturers for the valuable help they have rendered. Virtually all aircraft manufacturers in the United States have aided us materially, either directly or indirectly, in establishing and coordinating the standard practices for aircraft template making. In this regard Aero Publishers feel particularly grateful to Beech Aircraft Corporation, Bell Aircraft Corporation, Boeing Aircraft Company, Consolidated Aircraft Corporation, Curtiss-Wright Corporation, Douglas Aircraft Company, Hughes Aircraft Company, Lockheed Aircraft Corporation, Glenn L. Martin Company, North American Aviation, Inc., Northrop Aircraft, Inc., Republic Aviation Corporation, Ryan Aeronautical Company, Vega Airplane Company, and Vultee Aircraft, Inc.

INTRODUCTION

Paralleling the rapid advancement of the aviation industry has been the ever growing problem of training new personnel. This problem becomes more acute as the industry is forced to hire men who have had little or no technical training.

A few pointers and a little guidance from authoritative sources, makes a considerable difference in whether the young man just starting is going to make the grade, or just be one among thousands of average workers with average jobs.

Template layout is an old engineering procedure, probably first used in ship building and later in a modified form for automobile design. The modern aircraft manufacturers have adopted this method of maintaining the original development information for further use and reference. The technique used in the early stage of templating, although leaving much to be desired, was rapidly improved through the application of modern engineering principles.

Today templating is almost universally used throughout the aircraft industry and has brought about a complete change in the manufacturing of airplanes on a mass production basis, because information furnished the shop in this form greatly facilitates manufacturing. Layout of flat pattern of sheet metal parts, radial drilling, checking of **concave** and **convex** contours, router patterns, trimming parts, and checking angles are all accomplished with the aid of templates of the various types discussed in the following chapters. The problem of duplicating templates in order to fulfill the need for more than one template has been satisfactorily met by the photographic method. This method duplicates engineering drawings into the form of lines on metal which will later be cut out to make various kinds of templates. As the original drawing is left intact it is possible to retain this material for future reference.

The template department of an aircraft factory is a close associate of the engineering department. In some plants, it is an integral part. The template maker is one of the intermediaries between the engineer and the mechanic in the shop. Taking the engineer's ideas from the blueprints, the template maker transfers them into the form of a template in such a manner that they can be used by the mechanics in the factory.

CHAPTER I

TEMPLATES AND THEIR USES

1:1 Templates.

In the aircraft industry the word template is commonly used to identify a thin metal plate or other suitable material which may be used as a guide or pattern and generally includes the profile, contour, layout of holes and/or bend lines of a part, or an assembly layout of several parts.

1:2 Template Material.

The template material is usually metal and should be sufficiently soft to be easily worked, i.e., drilled, filed and cut by the ordinary sheet metal working tools. It should be of sufficient thickness to lie flat with its own weight and yet not too thick or else cutting, filing and punching becomes a problem in itself. Most commonly used metals are **body steel, galvanized iron** and in some cases **ST alclad** or **terne plate,** approximately $1/32''$ or $3/64''$ thick. For certain large templates where added rigidity is required, metal, .064, or approximately $1/16''$ in thickness may be used. Terne plate is used in some localities because of its non-corroding qualities due to a surface coating of a lead alloy consisting of 80 per cent lead and 20 per cent tin.

1:3 Template Makers.

The general qualifications of a template maker are an ability to exercise sound judgment and to do a considerable amount of independent thinking. He should have good steady nerves and good eyesight. Exactness, precision, and a great patience for details are all necessary characteristics of his personality.

The template maker works in a very close coordination with the engineering department of an aircraft company. In order to meet the demands of the work, it is desirable that he have completed certain necessary preparatory subjects in high school or college. Algebra, plane and solid geometry, trigonometry, and drafting are necessities. Wood and sheet metal shop work are closely related subjects. The applied material given later on in this text, however, should enable the average person to perform the work of a template maker in a very satisfactory manner.

To train for advancement on the job, the template maker should

make it a point to improve his drafting and ability to read blueprints. Template layout procedure should be studied. He should endeavor to become proficient at his work, to inspect templates so as to recognize errors in layout or making. For advancement to supervisory positions, trade ethics and better human relations should be studied and practiced.

1:4 Use of Templates.

Individual templates can be classified only in a general manner because the various names and types are not standardized in all shops.

A general classification is as follows: Angle Template; Block Template; Contour Template; Drill Template; Drill Jig Template; Flat Template; and Shrink Template.

1:5 Angle Template.

An angle template is used to mark the end cutoffs, profile, and layout of holes of a part made from extruded, or formed angle, or T-section stock. It is generally made to fit on the inside of the part, unless the part is exceptionally small, in which case the template would be made to fit outside the part; for the reason that such a template is too small to handle conveniently and would also be easily lost. The angle template must be made in such a manner as to clear the radius of the part upon which it is used. Holes are located on the part through small drilled holes in the angle template, usually a #40 or #50 drill is used.

An angle drill template is similar to an angle template except that its sole use is the direct drilling (as from a drill jig) of holes

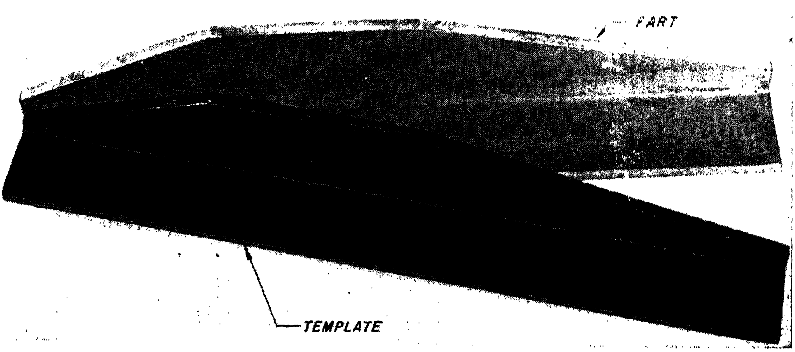


Fig. 1:1—Angle Template

into an extruded or formed angle. Normally an angle drill template fits on the outside of a part, and is made as shown in Fig. 1:2 (a) and applied as shown in Fig. 1:2 (b).

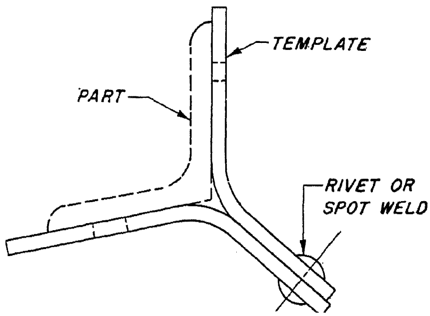


Fig. 1:2 (a)—Angle Drill Template
End View

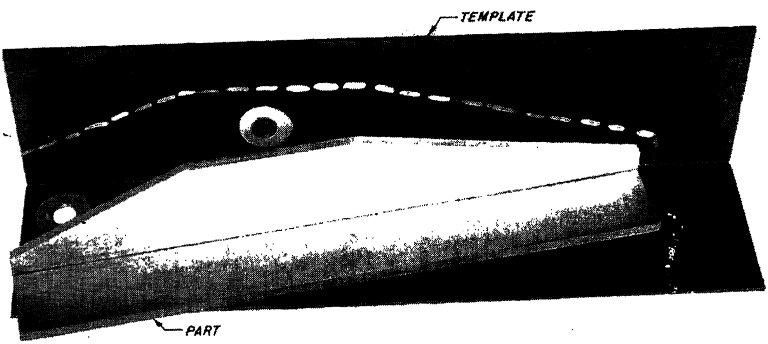


Fig. 1:2 (b)—Angle Drill Template

1:6 Form Block Template.

A block template indicates the exact profile of a **form block. Pin holes** in the flat templates are drilled to coordinate with pin holes in the block template, which are placed so as to locate correctly the corresponding pins in the form block.

1:7 Master Template

A master template, many times called Master Contour Template, shows all of the **mold line** contours for a particular section of

the airplane, such as the horizontal stabilizer rib contours or the outer wing rib contours. All contours included in any one master template have common horizontal and vertical reference lines. Information required for making master templates is taken from **scrieve boards,** basic dimension reports, and engineering drawings. Master templates for symmetrical sections, such as fuselage bulkheads, are often made for only one-half the contour. Pin holes are provided on the center line of symmetry so that the template is simply turned over to obtain the complete contour. In most cases small holes, usually #40 or #50, are drilled at close intervals along the contours of master templates in order that these contours may be transferred to other templates by the use of a **duplicating punch.** Refer to Figs. 2:9 and 2:10:

1:8 Part Contour Template.

A part contour template is used to check the contour of a part. See Fig. 1:3. On the face of this template a sketch is often painted or scribed, showing the way in which it is to be used. Variations of this type of template are the contour template for a **die** and the contour template for a **punch.** The latter is used to check the contour of a male die. The terms "male" and "female" die are particularly associated with the dies used in conjunction with the **drop hammer** and **hydraulic press.** These terms are further discussed in Chapter 2. Typical contour templates are shown in Fig. 1:4, a and b as applied to the specified sections A, B and C on the part or male portion of a die, and as applied to the female portion of the die.

1:9 Box Template to check die.

A box template is a group of contour templates set up together in a honeycomb formation. (See Fig. 1:5.) The purpose of the box template shown in this figure is to check the contours of a female die or full size pattern, and also to check the mating box contour template used to check the contour of the punch of a large die, or full-size pattern. Similar to this is the box shrink template, which is used to check the contours of a **shrink pattern** or to serve as a framework for a **plaster pattern.** See article 1:19.

1:10 Drill Template.

A drill template is made of sheet template stock fitted with hardened steel bushings or plates used as **drill guides.**

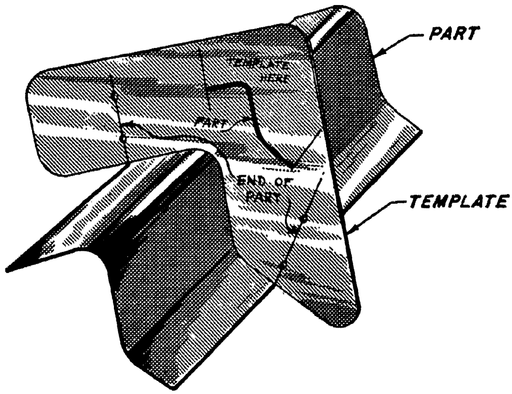


Fig. 1:3—
Part Contour
Template

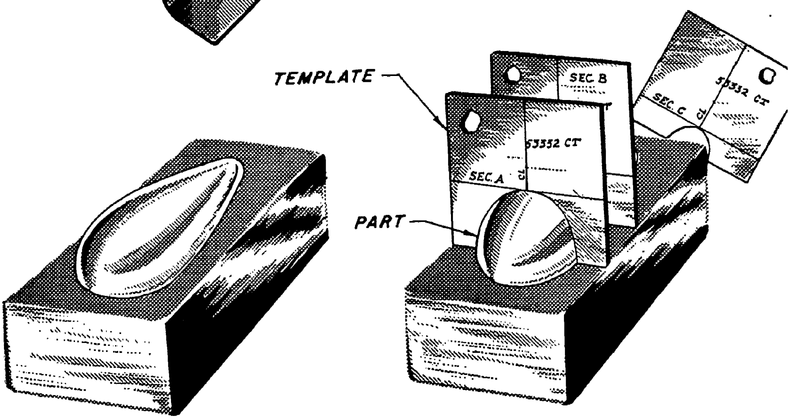


Fig. 1:4 (a)—Contour Template to check punch

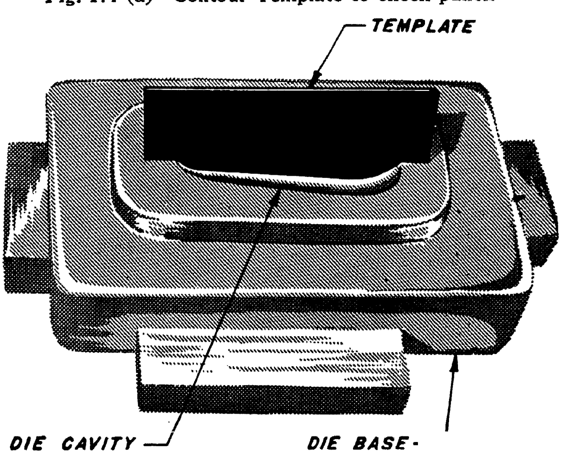


Fig. 1:4 (b)—Contour Template to check die

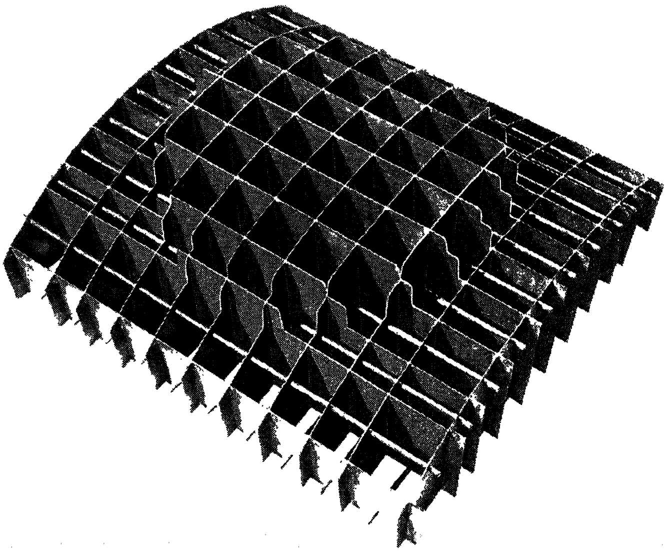


Fig. 1:5—Box Template

1:11 Drill·Jig Template.

A drill jig template is used solely by the tool departments to lay out holes in steel assembly jigs or other tools.

1:12 Radial Drill Template.

A radial drill template is used as a drill guide to drill flat sheet metal parts or blanks on the **radial drill.** It is provided with **pilot holes**[1] to receive the radial drill guide bushings. This template is not designed to indicate the developed profile of a part but in many cases extends beyond that profile to allow edge distance for the pilot holes when drilling holes near the edge of a part. For indexing purposes, two sides are used which are not parallel to one another and which coincide respectively with two sides of the flat template. Coordinated index-pin holes are quite often used for the same purpose.

[1] Any size pilot hole may be used as long as the pilot hole and the radial drill guide bushings are the same size. Commonly used sizes are 1/4″ or 5/16″ holes.

1:13 Flat or Developed Template.

The flat template, as its name implies, is the developed flat pattern of a sheet metal part of any number of bends of a various number of degrees and contours of various radii. This template is the basis for the layout of any metal part formed from sheet metal, and is of utmost importance to production. It is the purpose of this course to instruct the student especially in the development and making of this type of template. See Fig. 1:7.

There are two types of flat templates. One type is a developed flat pattern which predetermines the exact size and shape of material necessary to make a part. The other type is a flat pattern in-

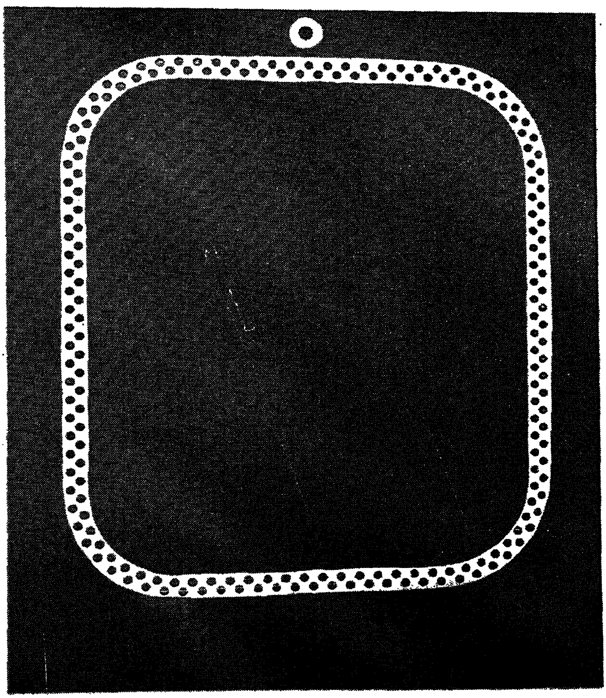


Fig. 1:6—Radial Drill Template

dicating the size and shape of material required to make a part, but which must be trimmed after it is formed or drawn.

The first type shows the blank profile, the complete layout of holes, and often the bend lines. This type of a template is mathematically developed.

The second type is used for drop hammer parts and for other formed or drawn parts which should be trimmed to drawing dimensions after being formed, or whose templates cannot be developed mathematically. This template shows the blank profile, including excess material when required for forming. It is developed by trial and error.

1:14 Form Press Template.

A form press template is a formed piece of deep-drawing body steel whose contour is such that it will **nest** against a given part for which it is made. It is used to mark for trimming, to check the

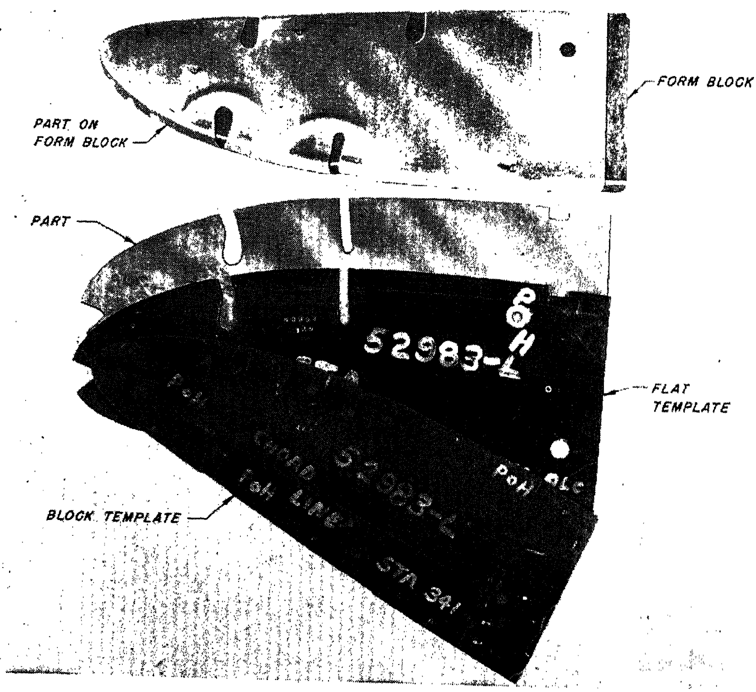


Fig. 1:7—Flat Template

contour and profile of, and often to drill formed or drawn sheet metal parts. Such parts are usually drop-hammer parts, some hydro-press parts, and any drawn or formed sheet metal part, the profiles of which are impracticable to develop in the flat pattern. See Figs. 1:8 (a) and (b). The form press template is often an inexpensive substitute for a wood or steel box drill jig.

1:15 Gage or Inspection Template.

A gage template is designed for checking the accuracy of a completed part. In one form it is similar to a part contour template, except that it is made so as to bound a part on more than one side. On the face of a gage template a sketch is scribed or painted, showing how it is used.

1:16 Marking or Trim Template.

The term "marking template" is generally applied to a template designed to fit on the flat surfaces of extruded sections or castings, used to mark cutoffs, cutouts, and hole layouts. Holes in the part are located through small holes usually #40 or #50 pilot holes in the template, and radius tabs are used where necessary.

1:17 Nibbler Template (or Block).

Nibbler templates are not truly templates as defined in 1:2, but, for shaping flat parts, they are actually blocks made of masonite or duraluminum; and a nibbler template for shaping formed parts, such as tubing, is actually a jig or fixture. Nevertheless such tools are called nibbler templates because they serve as patterns for the nibbling machine to follow.

1:18 Router or Shaper Template.

A router template consists of a sheet of plywood to which are riveted radial drill templates for a group of parts to be drilled on the radial drill and subsequently profiled on the undercut router. The drill templates, for parts made of the same type and thickness of material, are placed in a group which will allow a minimum of waste between parts. The size of a router template is governed by the size of the router table.

1:19 Shrink Template.

A shrink template is a contour template made with shrink allowance (oversize). It is used to make shrink patterns for molds or dies used in the drop hammer. See Fig. 1:9 on page 17.

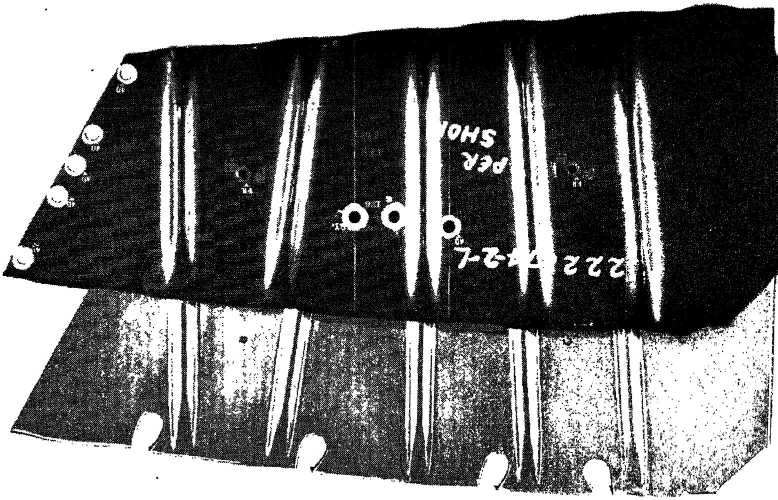


Fig. 1:8 (a)—Form Press Drill Template

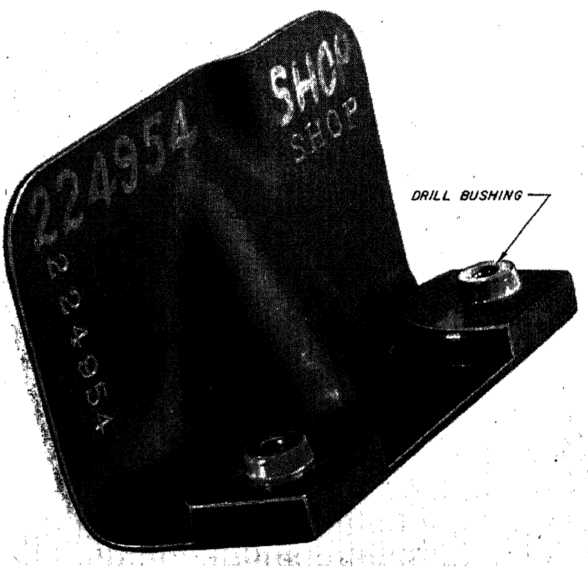


Fig. 1:8 (b)—Form Press Drill Template

1:20 Summary.

The various aircraft manufacturers differ a little in the making and use of templates from that as set forth in this chapter, but generally the procedure is the same. Some manufacturers make their templates out of body steel, galvanized iron, or terne plate, while others may use 24 ST Alclad. The gage (metal thickness) varies from .032 to .064. In some factories, the template department is an integral part of the engineering or lofting department. Template codes and methods of marking will vary for nearly every plant. Allowable tolerances vary from ± .005" to ± .010". A tolerance of ± .005 is within reasonable working limits if a man is careful.

Upon employment, the template maker will learn the template designations, shop procedures and any informative template cod-

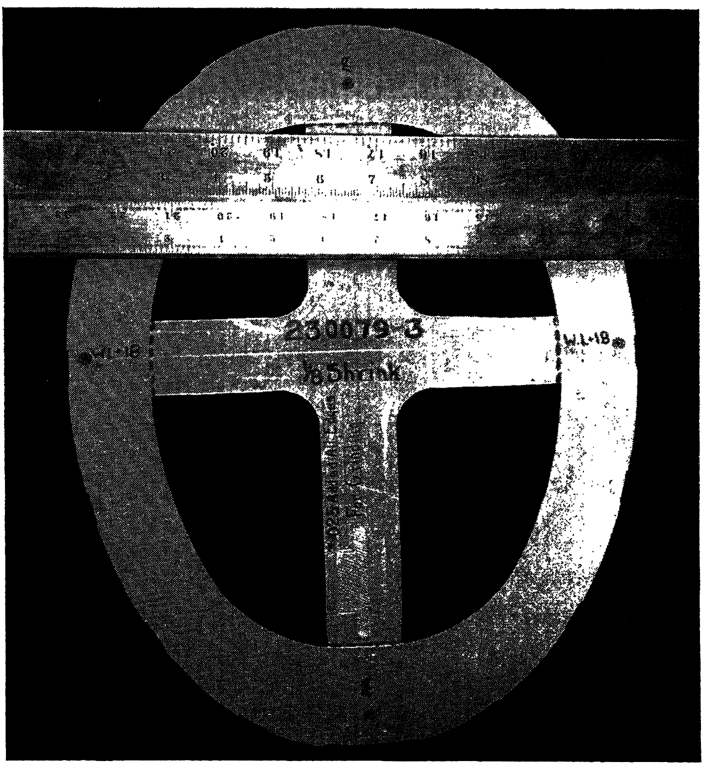


Fig. 1:9—Shrink Template

ing by reading the company's template manual, or in some cases by instructions from lead men and supervisors.

Analyze each new job carefully before starting the work. Remember—**"The scrap pile can, to a large degree, measure the success or failure of an organization."** Every part must be made exactly according to the blueprint or the part is rejected. The various operations required to produce an airplane from the initial stages on the design board to the final O.K. on the completed plane have been subjected to a series of frequent checks and inspections. This is accomplished by the care and pride each workman takes in his work and the scrutiny of checkers and inspectors at each stage of progress toward completion. Inspection problems are simplified by the use of the templates because the dimensions of parts do not always have to be checked with the drawing. In most cases this can be accomplished by simply laying the part on the full size template.

REVIEW QUESTIONS

1. What is a template? How is it used?
2. What are the materials most commonly used in template making?
3. Name at least seven classifications of templates.
4. How is an angle template fitted to the part? How is an angle drill template fitted to a part?
5. What does a block template indicate?
6. What is a master contour template? What is the source of information for making a master contour template?
7. Give two variations of the part contour template. How are they used?
8. How is a drill jig template used?
9. How is a radial drill template used? Does it indicate the developed profile of the part?
10. How is a flat template for a drop hammer part developed?
11. What is a form press template? Give four uses of a form press template.
12. Why are sketches placed on some templates?
13. How are the centers of holes located on a part by means of a template?
14. How does a gage template differ from a part contour template?

15. Give three uses for a marking or trim template.
16. How are router templates used?
17. What is meant by development?
18. What relation has the template department to the engineering department?
19. How are inspection problems simplified by use of templates?
20. What should the template maker do to acquaint himself with the complete shop procedure of an aircraft company immediately after employment?

CHAPTER II.

AIRCRAFT FACTORY NOMENCLATURE AND RELATIVE SUBJECTS

2:1 Orientation.

In addition to any specific application to templates, probably the first thing that a prospective template man should know or acquire is a general knowledge of the language of the aircraft manufacturing industry. He should learn of the parts and tools where templates have a direct application and as soon as possible, begin in a general way to absorb the technical language of the engineer, the shop man, and the aviation mechanic. He should make it a point to read on allied subjects in order to talk intelligently in aviation terms.

Many good technical aeronautical magazines are published. A man who is intending to make aviation his career should make it a point to subscribe to one or more of these trade journals in order that he may more readily keep abreast of the latest developments.

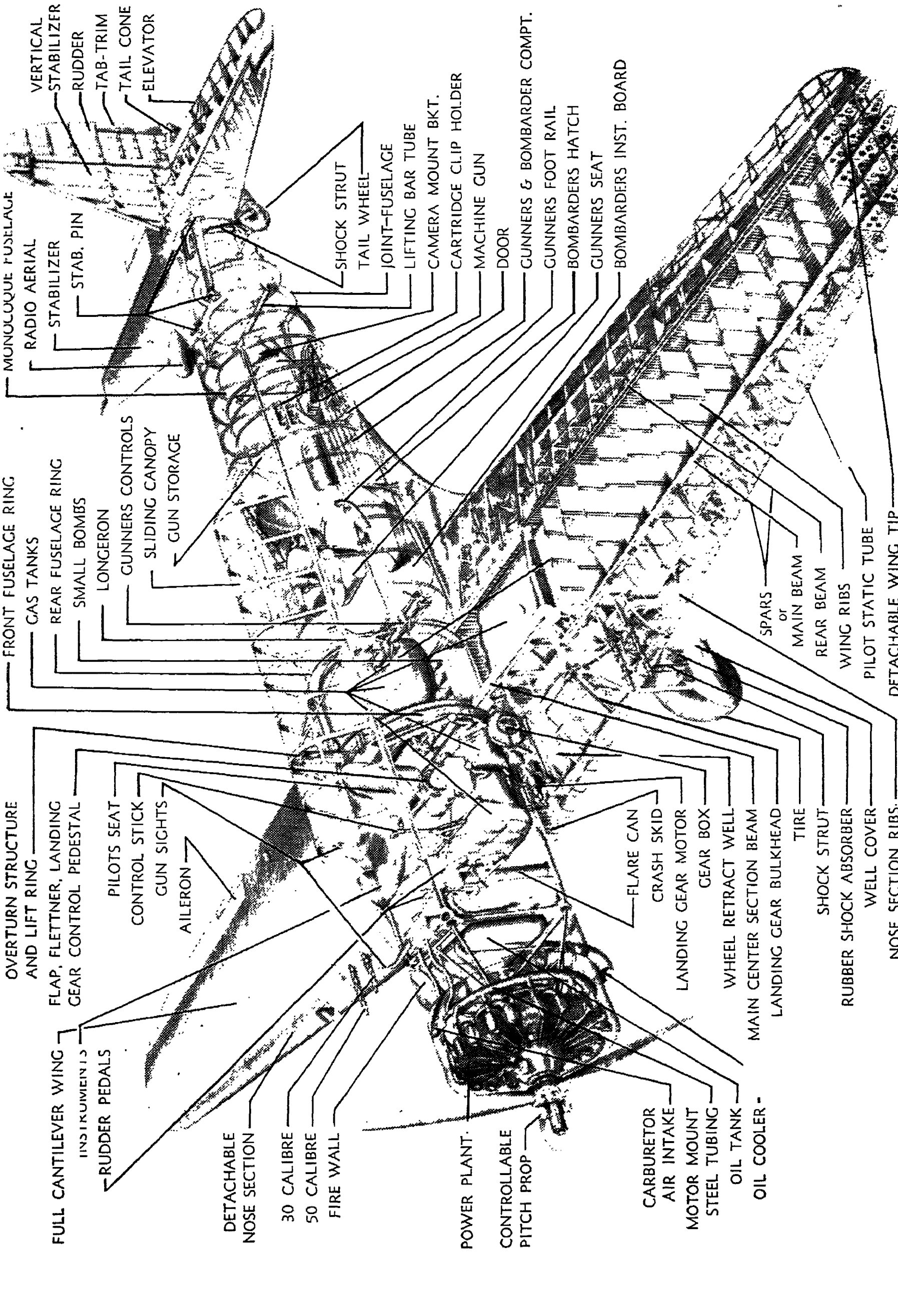
For the benefit of those who are beginning in the aviation industry, we will, in the next few paragraphs, outline some related information that may assist him in getting acquainted with his new study and supply a general picture of his future work of laying out and making templates.

2:2 Airplane Nomenclature.

With the aid of newspapers, magazines, radios, etc., the general public is becoming more acquainted with airplane terminology. However, since a template maker will have occasion to make templates on countless parts, both small and large, it is considered advisable, especially for the beginner, to give a brief resume of airplane nomenclature. Also there are a few notable cases of misconceptions and misnomers which have crept into the aviation language, e.g., calling an airplane a "ship" instead of "airplane" or simply "plane" and referring to "tabs" as "Servo Controls," etc.

The following nomenclature discussion will necessarily be limited to those aircraft parts which require templates before they can be manufactured economically or conveniently.

Figure 2:1 indicates the nomenclature of the parts which are


VERTICAL STABILIZER
RUDDER
TAB-TRIM
TAIL CONE
ELEVATOR
MONOCOQUE FUSELAGE
RADIO AERIAL
STABILIZER
STAB. PIN
SHOCK STRUT
TAIL WHEEL
JOINT-FUSELAGE
LIFTING BAR TUBE
CAMERA MOUNT BKT.
CARTRIDGE CLIP HOLDER
MACHINE GUN
DOOR
GUNNERS & BOMBARDER COMPT.
GUNNERS FOOT RAIL
BOMBARDERS HATCH
GUNNERS SEAT
BOMBARDERS INST. BOARD
FRONT FUSELAGE RING
GAS TANKS
REAR FUSELAGE RING
SMALL BOMBS
LONGERON
GUNNERS CONTROLS
SLIDING CANOPY
GUN STORAGE
SPARS or MAIN BEAM
REAR BEAM
WING RIBS
PILOT STATIC TUBE
DETACHABLE WING TIP
OVERTURN STRUCTURE AND LIFT RING
FLAP, FLETTNER, LANDING GEAR CONTROL PEDESTAL
PILOTS SEAT
CONTROL STICK
GUN SIGHTS
AILERON
FLARE CAN
CRASH SKID
LANDING GEAR MOTOR
GEAR BOX
WHEEL RETRACT WELL
MAIN CENTER SECTION BEAM
LANDING GEAR BULKHEAD
TIRE
SHOCK STRUT
RUBBER SHOCK ABSORBER
WELL COVER
NOSE SECTION RIBS
FULL CANTILEVER WING
INSTRUMENTS
RUDDER PEDALS
DETACHABLE NOSE SECTION
30 CALIBRE
50 CALIBRE
FIRE WALL
POWER PLANT
CONTROLLABLE PITCH PROP
CARBURETOR AIR INTAKE
MOTOR MOUNT STEEL TUBING
OIL TANK
OIL COOLER

typical of one type of airplane. Careful inspection of the illustration will show the application of the various terms. This illustration shows a countless number of parts which require templates before they can be made. It is seen that the fuselage is the "body" of the plane, and attached to the fuselage is the center section of the wing. The center section is generally the wing root section. On most modern multi-engined airplanes, it carries the landing gear loads, and supports the engine nacelles, fuel tanks, etc.

In most cases the wings are attached to the center section either by joining the wing spars to the center section spars or as in the case of a stressed skin wing, by means of joining the skin and spars. In many instances, particularly in small airplanes, the wings and center section are built as one unit. The spars are the main strength members running from wing tip to wing tip and are enclosed between the upper and lower surfaces of a wing. Ribs are attached to the spars at approximately right angles and spaced at regular intervals along the spar to determine the contour of the wing, and support of the skin or covering. Ribs are also used in the tail surfaces and various control surfaces. Ailerons are the controllable surfaces at the trailing edge of the wing near the tip. The function of the ailerons is to impart a rolling motion on the airplane, i.e., movement about the longitudinal axis. The ailerons are connected to the pilot's control stick or wheel in such a manner that as one is raised, the other is lowered, thereby securing either lateral balance or the desired angle of bank.

2:3 Flaps.

Flaps are movable surfaces connected to the rear portion of the wing, generally inboard of the ailerons, and connected to the wings either by means of a hinge, a slide track, or both. The flap surface is moved down or back and occasionally both down and back to create added lift and drag when the airplane is being landed.

2:4 Empennage.

The empennage is the tail group consisting of rudder, fin, horizontal stabilizer, and elevator. The rudder is used in conjunction with the ailerons to steer the airplane, i.e., to impart a yawing motion about the vertical axis. The fin, a stationary vertical surface, acts as a stabilizer to provide directional stability. The stabilizer is a horizontal member either fixed or slightly movable which aids in securing longitudinal stability or to prevent the airplane

from pitching. The airplane is made to climb or descend through use of the elevator, a movable airfoil hinged to the rear portion of the stabilizer.

2:5 Trim Tab.

A trim tab or tab as it is often called, is shown as a small movable portion inset into the trailing edge of the rudder. Tabs are also used at times on the ailerons, and elevators. By changing the angular setting of a tab a pilot can adjust the flying position of the main surface to which they are attached. The net result is that the airplane can be trimmed to fly "hands off," which means that the airplane under normal flying conditions will be so balanced by the air controls that it will have a tendency to fly itself automatically on the predescribed course or flight attitude.

Servo controls look very similar to tabs, but are actually a sub-control for any single large control or system of controls. A Servo control is actually a means of fully actuating the main control to which it is attached.

2:6 Landing Gear.

The landing gear of an airplane, consisting of the main landing wheels, the tail wheel or skid and the associated brakes, oleo shock absorbers and struts, supports the airplane on the ground. Struts, as used in the landing gear, are the connecting members between the landing gear and the airplane. They are usually streamlined by the use of fairings if used on a non-retractable landing gear. An oleo shock absorber is an oil dampening device that depends upon the flow of oil through an orifice for its shock absorbing effect.

2:7 General Types of Construction.

Inside of the airplane where the great mass of small parts are, we find that the fuselage may be either made up of various members such as tubes or other structural shapes, utilized as braces, or they may be of the stressed skin type (monocoque), which means that there is a minimum of internal members used as stiffeners or braces. The loads are carried by the outside surface (skin) of thin metal or wood.

The wings of an airplane may also be of the same two general types of construction which are used to make fuselages. The simpler wings have spars and ribs connected together and are braced by wires or struts. This structure is then covered with fabric and dopes (varnished with a special preparation). The fabric

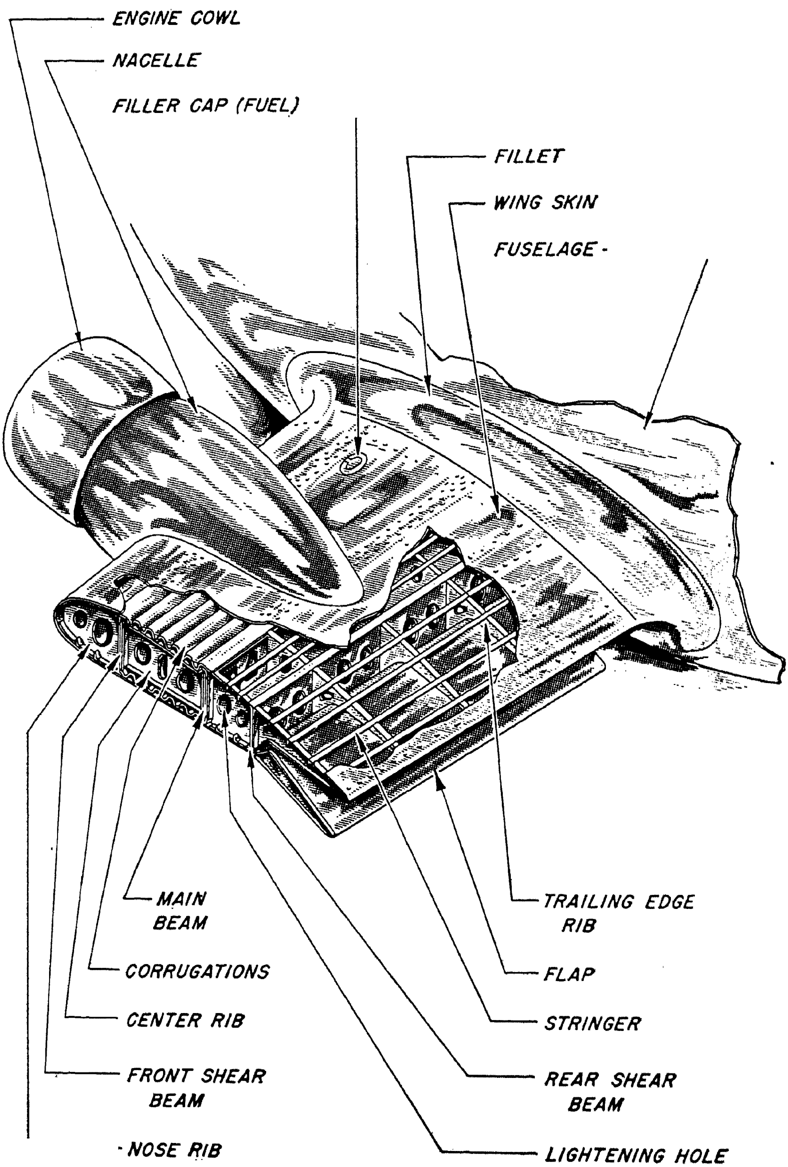


Fig. 2:2—Typical All-Metal Construction

covering carries only a vertical load (lift). The more complicated and larger wings are composed of less inside structure (ribs, spars, etc.) which is covered by stressed skin of wood or metal and which carries all the loads imposed on the wing.

Inside the fuselage are to be found such general parts as bulkheads, rings, gussets, stringers, stiffeners, etc.; and the wings contain such parts as ribs, stiffeners, gussets, tringer, par (beam), ribs, etc., all of which call for templates.

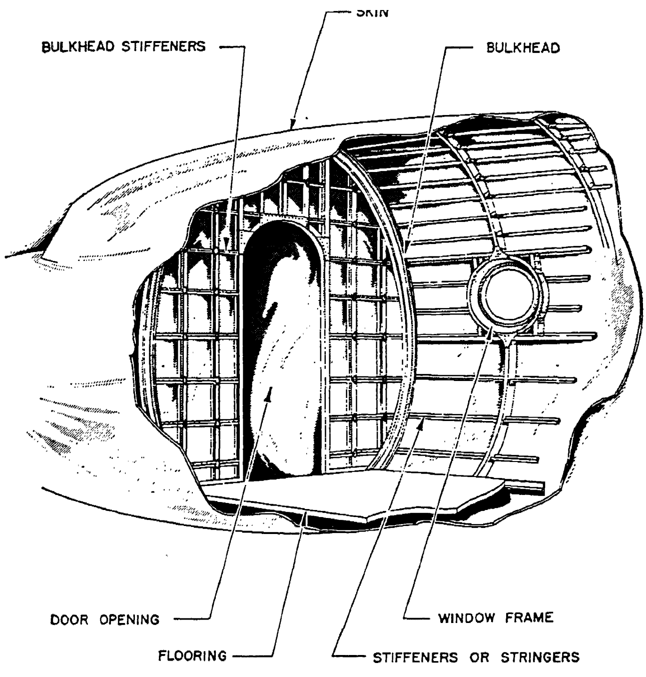


Fig. 2:3—Typical Stressed Skin Fuselage Construction

2:8 Lofting.

Lofting is the procedure by which a full sized layout of a given body is made on the loft floor. The loft is oftentimes an integral part of the engineering department and is closely associated with the template department. The results of the various lofting operations are transcribed to a scrieve board, a sheet of wood or metal, in the form of full-size contours and other measurable lines, then master templates are developed from data taken from scrieve

board layouts. All contours of a particular section of the airplane are laid out on the loft floor.

Fig. 2:4—Loft Floor

The following contours and intersections may be developed upon application of the proper lofting methods.

a. Fuselage Contours
   Shape and Size of Bulkheads
   Flange Angles of Bulkheads
   Stringer Locations
b. Nacelle Contours
c. Wing Tip Contours
d. Fillet Contours
e. Wing-Fuselage Intersection
f. Stabilizer-Fuselage Intersection.
g. Nacelle-Center Section Intersection
h. Miscellaneous additional information.

2:9 Template Making. (General)

The making of templates is to be coordinated, wherever possi-

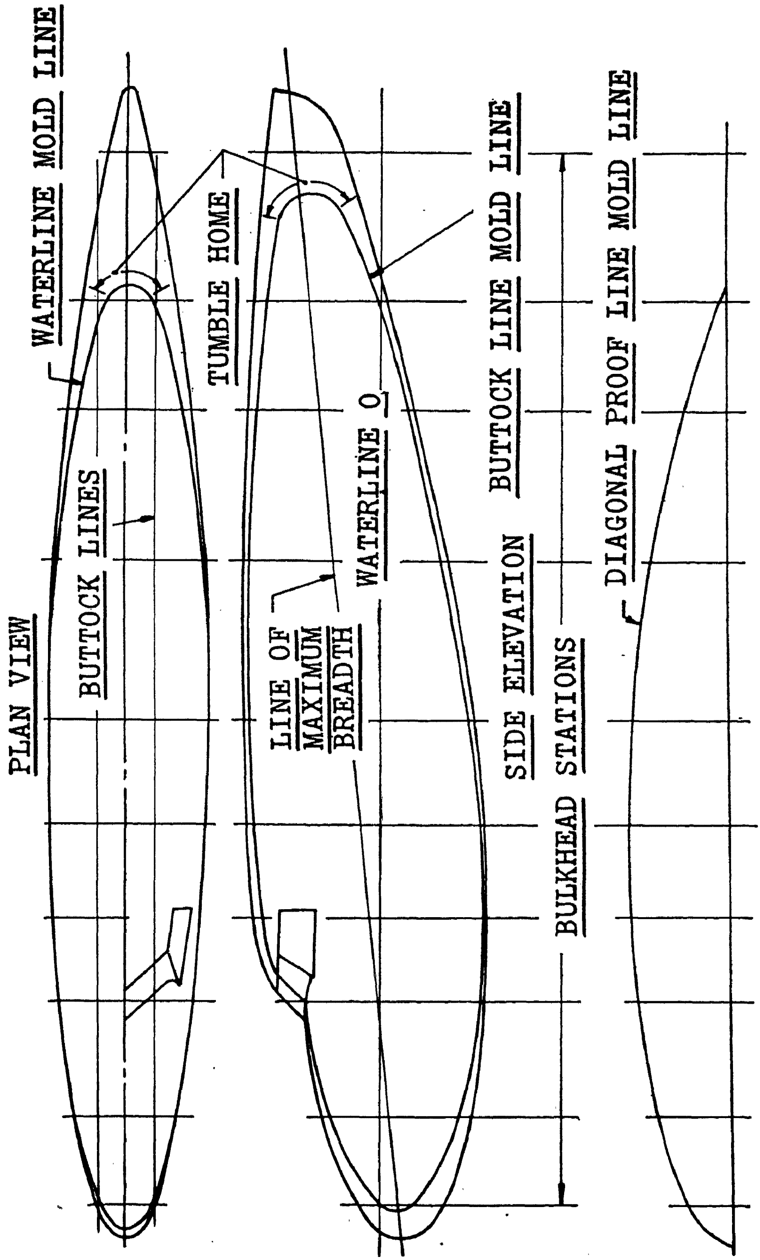


Fig. 2:5—Loft floor layouts

ble, with the work being done on the loft floor. The general policy with regard to templates is that they should be used extensively to convey dimensional information to all shop departments.

2:10 Loft and Template Nomenclature. (General)

The following are a few general terms which constitute the main part of loft and template nomenclature.

Base Line.

The base line is an edge view of a horizontal plane which is used as a zero point from which to measure all vertical ordinates.

Bend Allowance.

Bend allowance is the amount of sheet metal required to make a bend over a specific radius. The inside radius is most frequently used in aircraft work. The calculation is based on the thickness of the metal, the type of metal used, the radius of the bend involved, the degree of bend, and the use of bend allowance charts which are derived from an empirical formula.[3]

Bend Lines.

Bend lines are used on templates to indicate the extent of material used to make a bend or angle. Not all aircraft manufacturers use them. Some prefer to use only the mold line to indicate the bend. See Fig. 6:21.

Block Lines.

A block line is a mold line formed by the inside surfaces of a formed part. The block line forms the edge of the block template. See Fig. 2:11.

Body Plan.

The body plan is a view looking forward. As for example, a fuselage body plan shows, in a single plane, all the frames or stations in their proper vertical and horizontal relations. See Fig. 2:6.

Buttock Line.

A buttock line is an edge view of a vertical plane passed through a body. The centerline of the body in the Plan View is taken as Buttock Line O. The planes of all buttock lines are parallel to the vertical centerline plane. See Figs. 2:5 and 2:6.

Diagonal Proof Line.

A diagonal proof line is an edge view of a diagonal plane

[3] See Chapter VI.

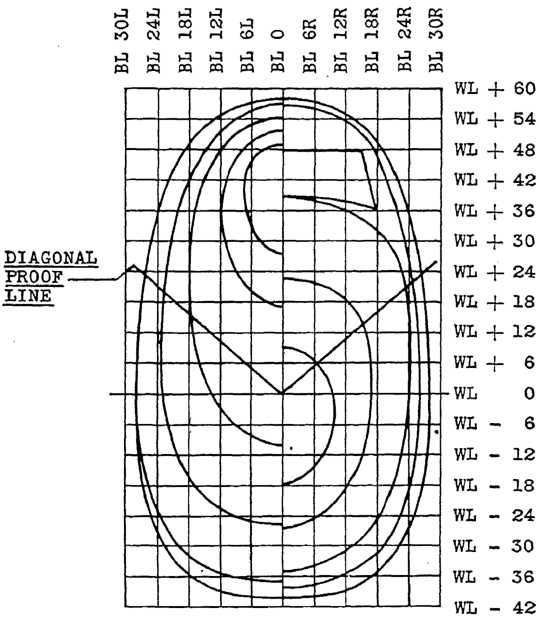


Fig. 2:6

through a body. These diagonal planes are passed through the body as a final check on fairness, or for the purpose of fairing portions of the body which undergo abrupt changes or curvature. See Figs. 2:5 and 2.6.

Loft Floor.

The loft floor is a large flat surface upon which full size layouts of airplanes are made—generally referred to as "The Loft."

Mold Line.

A mold line is the theoretical line formed by the intersection of two surfaces, such as the external edge of frames, stringers, or other shapes. See Fig. 6:4.

Pin Holes.

Pin holes are drilled in a flat template to coordinate with pin holes in a block template, which are so placed to locate correctly the indexing pins in the corresponding form block.

Radius Tabs.

Radii of corner relief cutouts may be provided with radius tabs,

that is, small projections of metal beyond the actual profile of the part, to receive pilot holes at the center of the radii.

Set Back.

In a part having bends or angles, set back is the difference between the sum of the lengths of the distances from the bend lines to the mold line, and the bend allowance.

That is, in Fig. 2:7

Set Back = (AB + BC) − arc AC

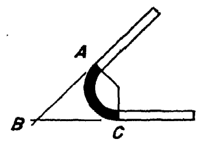


Fig. 2:7

Tumble Home.

The tumble home line is the abrupt change of curvature of a Mold Line, Buttock Line, or Water Line contour at the end of the contour. See Fig. 2:5.

Water Line.

A water line is an edge view of a horizontal plane passed through a body. The base line of the body is taken as water line 0. The planes of all water lines are parallel to the horizontal base line plane. See Fig. 2:5 and 2:6.

2:11 Lofting a Fuselage.

The following outline covers the general procedure which is used in fuselage lofting. Similar methods are used for lofting other bodies, such as nacelles, wings, tails, etc.

The Plan and Side Elevations are laid out full size on the loft floor from sketches provided by the Aerodynamic Research Group. See Fig. 2:5.

Fuselage stations which are to be accurately located are first laid out on these two elevation views. Typical stations could be (1) a section through the pilot's compartment, (2) a section at the propeller circle, (3) a section at the main beam of the wing, (4) a section at the rear seat of the cabin, or (5) a section at the rear of the fuselage which is to take the tail wheel supports.

The line of maximum breadth is laid out on the Side Elevation.

Known sections are laid out on the Body Plan Scrieve Board by transferring distances or **offsets** from the Plan and Side Elevations shown on the loft floor. See Fig. 2:6.

Preliminary contours of known sections are laid out on the Body Plan Scrieve Board.

Buttock Line Mold Lines and Water Line Mold Lines are laid out and faired with a **spline.** (Refer Fig. 2:5.) The smooth line characteristics of all contours and curves are checked by using Diagonal Proof Lines, after which all faired points are transferred to the Body Plan. See Figs. 2:5 and 2:6. When all curves are fair and smooth, the fuselage is properly lofted.

After such basic data are lofted, it is possible to lay out the additional fuselage stations that are necessitated by the structural requirements of the airplane. Stringers or stiffeners can then be located on each station contour and from these stringer points the bulkhead flange angles can be determined. The flange angles can be calculated or measured by utilizing (1) the distances between the fuselage contour lines as drawn on the Body Plan Scrieve Board and (2) the actual distances between the fuselage station as drawn on the Plan or Side Elevation. The former distance is referred to as the **tangent height** because it can be considered as the side opposite of a right angled triangle the base of which is equal to part (2) above—that is the plan view distance between stations. Thus, with the side opposite and the base known in any one of the triangles, it is possible to determine the flange angles either by trigonometry or by measuring them with a **bevel curve** or a **bevel stick.**

Station Locations: Small fractions, 64ths and 32nds, should be avoided wherever possible when locating stations, waterlines, or buttock lines.

Left Hand View: In general, all lofting is done as though the object were being viewed from the rear of the airplane looking forward showing the left hand side. Deviations from this convention should be clearly indicated.

Buttock Lines and Water Lines: All Buttock Lines and Water Lines are referred to according to their actual distance (usually measured in inches) from their respective zero lines. Thus, a line, which is parallel to the fuselage Water Line 0 and located at a distance 32¼ inches above it, will be noted as WL+32¼. Lines below Water Line 0 will be noted in a similar manner, such as WL − 18½.

Buttock Lines should be designated as L or R according to whether they are located to the left or right of Buttock Line 0, when the object is being viewed from the rear. The designation is written as BL 18 L. Refer to Fig. 2:6.

The spacing of the Buttock Lines and Waterlines used in an original construction is dependent upon the shape and curvature of the lines.

2:12 Scrieve Board Layout Procedure.

All layouts which are to supply permanent basic dimension information are to be placed on Scrieve Boards. Only one side of each Scrieve Board is to be used unless the layout on the opposite side is definitely obsolete and is marked as such. Scrieve Board Layouts are all full size. See Fig. 2:6.

All construction lines and cutting planes are identified by letters or numbers placed at both ends of the line. Lines about which views are rotated and from which offsets are measured should be marked RL (Rotation Lines). See Fig. 2:8.

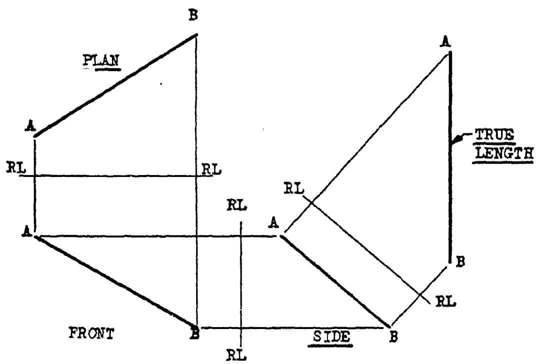


Fig. 2:8

Reference numbers and letters should be clearly marked on the Scrieve Boards.

2:13 Application of Loft Data to Layouts.

Layout Draftsmen and Designers who require contour information in order to draw a layout should consult the Loft Group. Contours may be traced by placing a sheet of layout paper over the Scrieve Board Layout and using a sharp pencil to trace the required contour.

All basic reference lines shown on the Scrieve Board should be indicated on the layout and properly designated.

Dimension information obtained from Basic Dimension reports and used in the drawing of a layout should be noted on the layout with a reference to the page and report number.

2:14 Application of Loft Data to Drawings.

Scrieve Board Layouts should be referred to on drawings wherever possible. Where contours and flange angles are to be obtained from Master Templates by the Shop, a definite note stating this fact must be shown. The following type of note is generally satisfactory.

NOTE: OBTAIN CONTOURS AND FLANGE ANGLES FROM MASTER TEMPLATE No. 193276.

Stations, Buttock Lines and Water Lines when shown on drawings, should be indicated by placing the proper designation in a 5/8" diameter circle at one end of the line.

Only actual stations which have definite meaning are to be shown on drawings, this includes bulkhead stations, wing rib stations, etc. Intermediate points should be dimensioned from the closest actual station line.

2:15 Development of Master Templates.

Master Templates are developed from data taken from Scrieve Board Layouts as well as from basic dimension reports and engineering drawings, and are laid out on template metal (or other suitable material). Holes may be drilled along the contours to allow them to be transferred to other templates with the aid of a transfer punch. See Fig. 2:9.

Master Templates for symmetrical shapes such as fuselage shell are generally made for only one-half of the object. Centerline pin holes are provided so that the half template may be turned over to obtain the complete contour. See Fig. 2:10.

2:16 Development of Block Templates.

Many Form Block Templates are made directly from a Master Contour Template. A Block Template is smaller than the **Mold Line** contour shown on the Master Template. The amount of the differ-

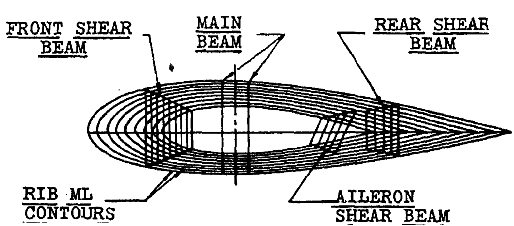


Fig. 2:9

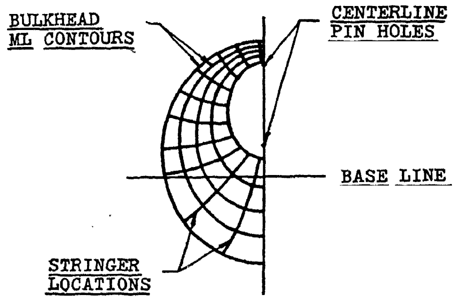


Fig. 2:10—Master Template, Fuselage

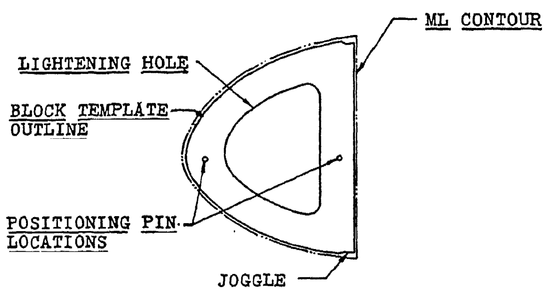


Fig. 2:11—Block Template

ence between the Master Mold Line contour and the block contour line is calculated by taking into consideration the thickness of the metal, the bend radius, and the angle through which the metal is to be bent. See chapter 6.

2:17 Development of Flat Templates.

Flat Templates are developed from Block Templates, or from drawings. When developed from Block Templates, a value may be calculated taking into consideration the flange widths, bend allowance, and metal thickness, and added directly to the Block Template outline, thus completing the Flat Template with a minimum expenditure of time and labor.

All information required to make a blank for a part should be shown on the Flat Template. Fig. 2:12 shows a Flat Template developed from the Block Template shown in Fig. 2:11.

An engineering drawing for a part, such as a nose rib, where

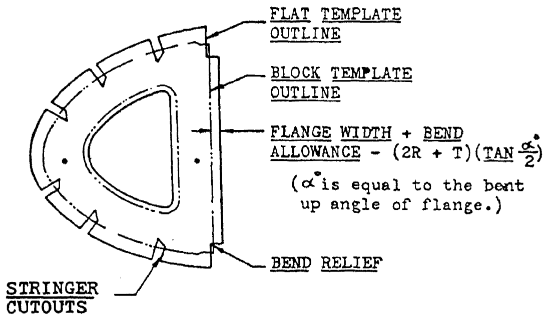


Fig. 2:12—Flat Template

basic information is supplied on the Master Template, should note this fact in the following manner:

NOTE: OBTAIN CONTOUR, FLANGE ANGLES, AND STRINGER LOCATIONS FROM MASTER TEMPLATE No. 190060.

Flange widths, odd cutouts, and other information not shown on the Master Templates should be given on the drawing.

2:18 Development of Miscellaneous Small Templates.

The various templates, such as Drill Templates, Marking Templates, etc., which cannot be developed directly from Master Templates, will be laid out from information furnished on Engineering drawings.

2:19 Limits.

Engineering blueprints are usually noted "Unless otherwise specified, limits are plus or minus $\frac{1}{32}$, etc." This note is for the finished part or the assembly, whichever the print may be for. However, it is general template practice to hold tolerances to within $\pm$ $\frac{1}{2}$ of one 64th (or $\pm$ .008).

This limit on templates is not unreasonable because it gives the workman in his shop, who makes the finished part, approximately the $\frac{1}{32}$ tolerance allowed on the print. This is possible because if the template is within plus or minus .008, the man in the shop can still be off .023 larger or smaller and the finished part will still be within the specified tolerance ($.008 + .023 = .032 = \frac{1}{32}$). However, if the template was large by $1\frac{1}{2}$ 64ths and due say, to the equipment or the human element, the part was cut out and bent up $1\frac{1}{2}$ 64ths larger than the template, then, when the finished part was checked, we would find that the product was $\frac{3}{64}$ larger than

the dimensions given on the blueprint, or $\frac{1}{64}$ larger than the $\frac{1}{32}$ of an inch allowed for tolerance.

Templates can be tremendous time savers for the shop because when they are followed closely, any number of parts can be made up exactly the same, thus giving us interchangeability between parts.

2:20 Jigs and Fixtures.

Jig builders and template makers are closely akin, both in making the tools for the fabrication, and assembly of the component parts of an airplane. A jig is a rigid structure of mechanism either of wood or metal, which holds parts in place while they are in some phase of fabrication prior to assembly, or which holds the component parts of a structure while it is being assembled or disassembled.

A fixture is somewhat similar to a jig. The chief difference being, the fixture in most cases, is a lower priced and simpler mechanism and apt to be a single purpose tool for holding parts during certain machine or hand operations. The term fixture is often applied to any work-holding device which is secured to a bench or a machine while work is being performed on a part.

Various types of assembly jigs are: Fuselage jigs, for erecting the fuselage (Fig. 2:13); wing jigs, for assembling the spars, ribs, and **skin** (Fig. 2:14); center section jigs; welding jigs, for holding tubing and/or metal fittings rigidly in place while being welded together; drill jigs (often made from drill templates); and mating jigs, adjustable jigs used to support a completed component part while it is being aligned and fitted to the main assembly. These are a few of the more commonly used jigs. Nearly every detail or final assembly in the aircraft industry is fabricated and assembled in wood or steel jigs.

2:21 Plaster Mock-up.

The Plaster Mock-up is a full-size three-dimensional copy of the airplane or some section thereof. It is made of metal contour templates, wood backing, wire reinforcing and plaster surfacing. The finished contour of a Mock-up gives the true surface or shape of the inside of the skin. All plaster mock-ups unless otherwise specified are built to $\frac{1}{10}$ of 1 inch per foot shrinkage. That is, a Mock-up covering an area ten feet (120 inches) long by shrink scale will measure 121 inches by standard scale. This $\frac{1}{10}$ expansion in Mock-up building is to offset the $\frac{1}{10}$ shrinkage of the kirk-

Fig. 2:13—Fuselage Jig

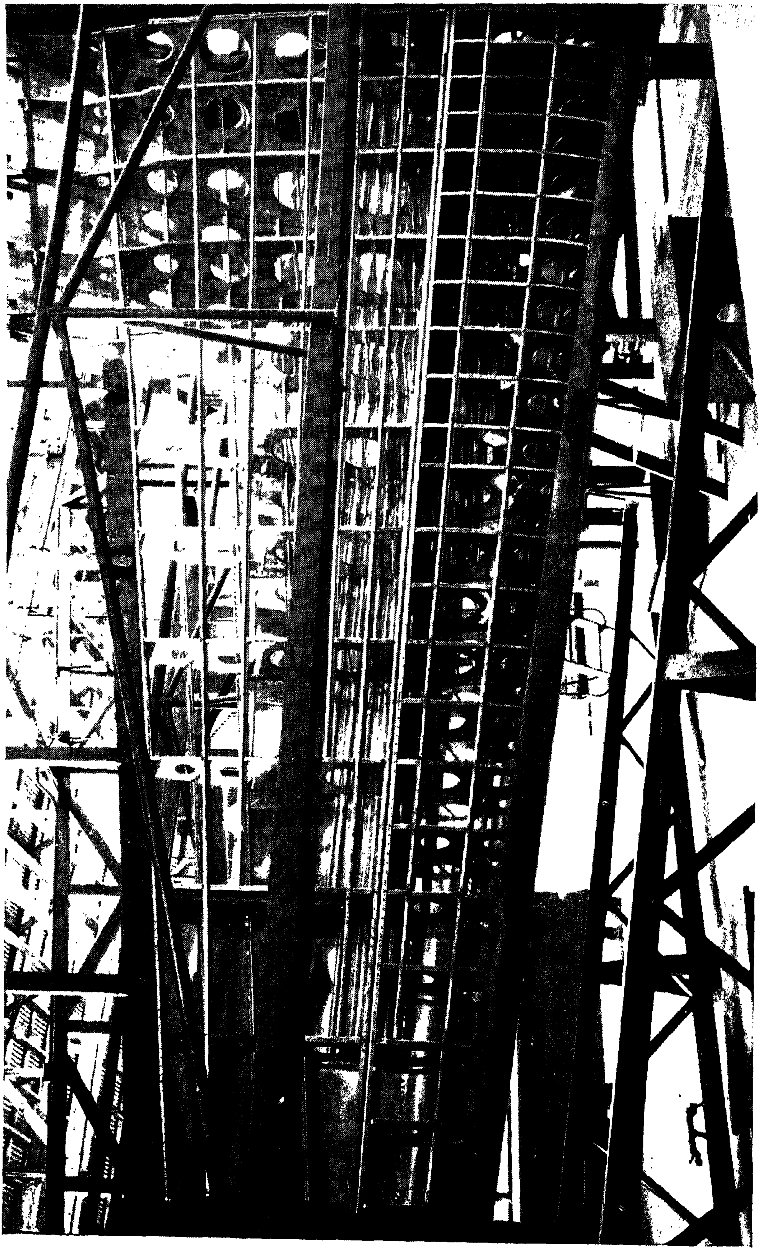


Fig. 2:14—Wing Jig

site from which drop hammer and hydro-press dies are usually made. This metal shrinks $\frac{1}{10}$ of 1 inch per foot, hence we speak of making Mock-up to $\frac{1}{10}$ shrink.

To plan, lay out, and construct a mock-up and develop usable patterns therefrom, one must be acquainted with blueprint reading having to do with various assemblies and parts. All basic reference lines must be learned and regarded as the ABC's of the work. Since the plaster mock-up builder is usually the first shopman to use the blueprints, very often working from pre-released drafts of the blueprint to be, he must have sufficient knowledge to be able to check against errors before they incure loss of time and material in production.

Templates for the mock-up are made from terne plate or galvanized iron, either .032 or .051 inch thickness according to the need of the job. For the larger contour cross-sections, the heavier metal is used. For small sections, lighter weight metal is sufficient. A line representing a cross section of the plane is accurately laid out by means of splining to given points known as half breadths and vertical heights, on a flat piece of template metal. This shape is then cut out and filed to close tolerances, (usually with ± .008 of an inch.) The knowledge of flat layout is necessary for the making of the template and for the layout of the cross section lines upon the table upon which these templates are to be mounted.

The use of power tools, such as the **band saw** for wood and metal, **arbor** and **dato saw, drill press, sander, grinder, router, joiner,** and **planer** are essential to the work. The surface of the mock-up table usually represents a vertical or horizontal cut through that portion of the plane for which the mock-up is being constructed. These surfaces, therefore, must be supported and braced in such a manner that they will remain absolutely flat and unwarped through the useful life of the mock-up. These tables must be built strong enough also to permit their being moved without damage to the mock-up.

When the table is completed and the proper line layout made thereon, the templates are then backed up with plywood in order to secure rigidity. A substantial cleat is fastened to the straight bottom edge and the template is then screwed fast to the table. The templates are then securely braced in a plumb position. This is done by running threaded rods through them with the necessary nuts and washers on each side. When the bolts and nuts are tight-

ened against the templates, they hold them securely in the desired position. See Fig. 2:15. Smaller holes are punched about ¾ of an inch in from the contour edge of the templates so that heavy wire may be passed through them, (See Fig. 2:16), and form a supporting network upon which galvanized screen wire is placed as a backing for the plaster as in Fig. 2:17.

A **scratch coat** of plaster is then applied, See Fig. 2:18, this coat being kept about ¼ of an inch below the contour. As this first application of plaster begins to set, it is scratched away from the side of the templates to prevent the expansion, incidental to setting plaster, from forcing the templates out of their plumb setting. It is obvious that if a template, which represents a portion of the contour at a point of rapid **tumble home,** should be moved either way from its plumb position it changes the contour and defeats the purpose for using a template at all. The crack or slit which results from scratching the plaster away from the templates is then filled with soft clay before the final or surface coat of plaster is applied. The scratch coat is usually shellacked before the final coat is applied, to reduce the suction and thus give more time to properly spline the surface application.

When the surface has been evenly **splined,** and proves to offer a **fair line** in all directions, it is then given a protective coat of clear lacquer. When duly checked by the inspection department, the mock-up (Fig. 2:19), is ready for the layout of all parts for which patterns are to be made from the mock-up. Here again a knowledge of blueprint reading is essential to the job. Since a greater portion of the layout is designed to be made in projection, various planes must be fixed from which by means of a surface gage, dividers, squares, straight edges and scales, the lines and radii can be accurately laid out. All layout lines such as mold lines, part cut-off lines and essential reference lines are carefully and lightly cut into the surface of the plaster and traced with an indelible pencil so that they will pick up or transfer to the splash cast when it is taken off.

The splash cast is a thin layer of plaster, backed by hemp fiber and a frame of wood or iron to help hold it in place. When a part has been laid-out on the mock-up and the lines have been cut and traced, a coat of **steric acid** is applied as a separator. A thin wood frame or a border of clay is often placed around the outline of the part thus laid out, and a creamy application of plaster is literally splashed or poured on until it is approximately ¼-inch thick, and

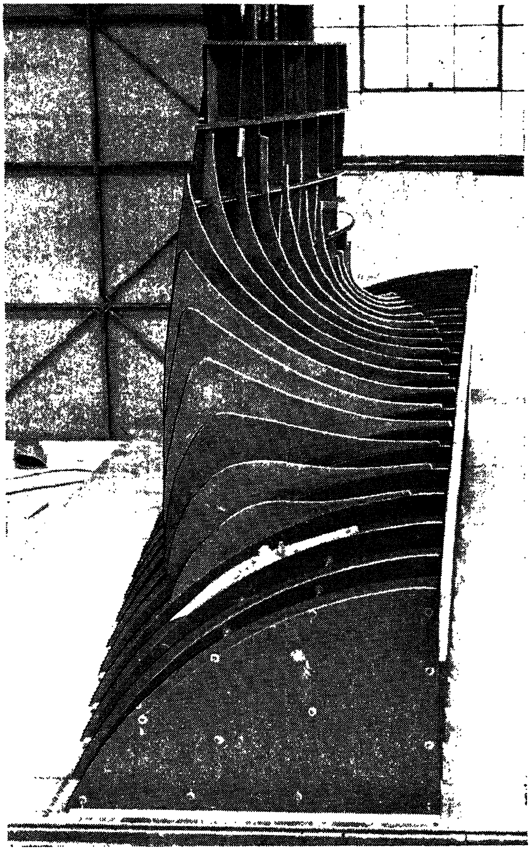


Fig. 2:15—Templates for Plaster Mock-Up

before this is set up a backing of hemp fiber mixed in an even thinner consistency of plaster is applied. The frame, which has been prepared in advance, is then tied to the back of the splash cast with the plaster saturated fiber, forming a sort of standard when the splash cast is taken away from the mock-up.

As soon as the splash cast is cold, it is turned over on a bench and the pattern for the part is developed on the layout lines which were transferred from the mock-up. The development of a plaster pattern means the building up of such offsets, joggles, frame thicknesses, corners, bevels, etc., that are needed to make a proper pattern for the part that is to be formed. In doing this due

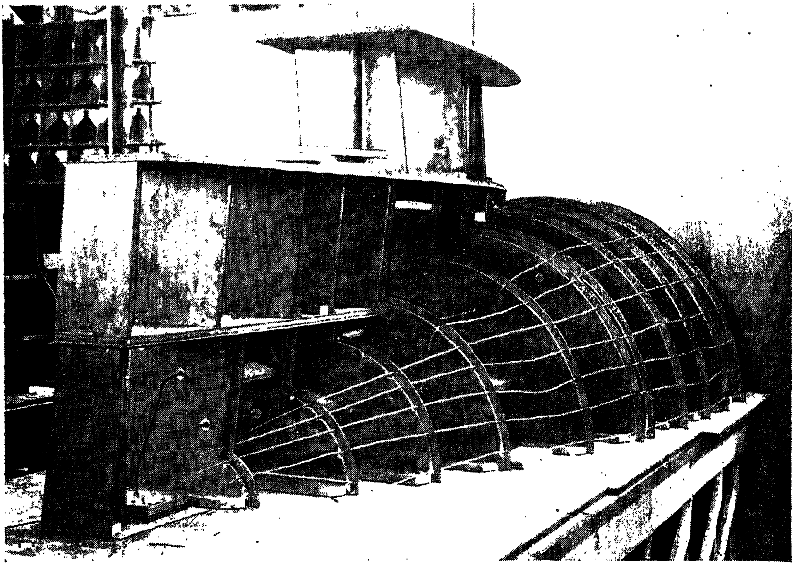


Fig. 2:16—Templates Cleated to Table and Backed With Plywood for Rigidity

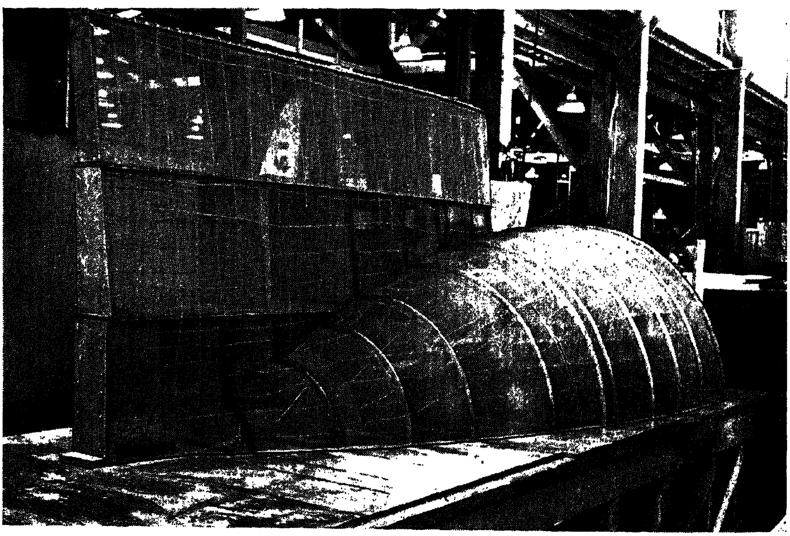


Fig. 2:17—Galvanized Screen Wire Backing for Plaster

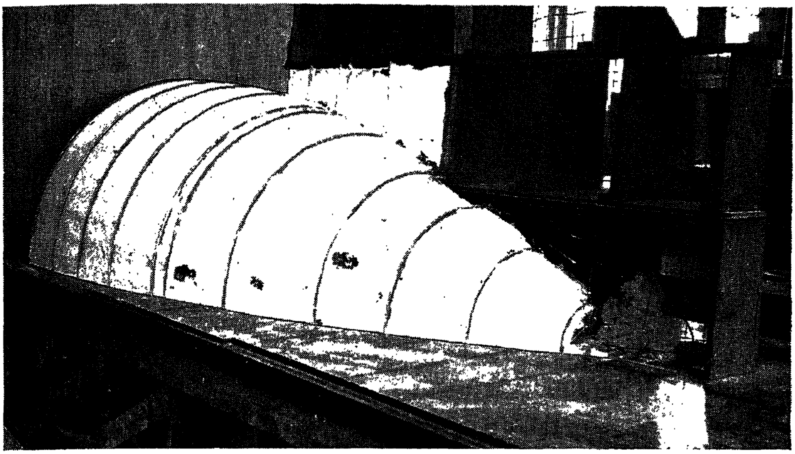


Fig. 2:18—Scratch Coat

consideration must be given to bend allowance, spring-back and proper draft for all sides and edges. All beadings, lightning holes, corrugations, too, must be so worked out as to insure proper draft, and make provision for metal thickness according to the side from which it is to be struck by the drop hammer or shaped in the hydro-press.

For **trial fillets** and fairings, modeling clay is very useful. Such fairings can be modeled in clay, and if they meet with engineering approval, they can be readily cast in plaster to form a more permanent plug or pattern.

The utility of the plaster mock-up and the plaster pattern is only partially discovered and is bound to increase in the aircraft industry, in fact, drill jigs, test templates, contour checks and various other useful tools, are constantly being made to facilitate the successful operations of many tooling devices.

2:22 Tool Maker.

The tool maker is primarily a bench worker having the ability to work within very close tolerances with hand tools. He should either be able to operate such power tools as lathe, shaper, planer, etc., or be familiar with their use. In many cases he must design the tool from the blueprint on the part, determining all machining and processing to be done in the machine shop, and finish the tool on the bench. Some of his principle jobs in the aircraft industry are the making of form blocks and punch press dies.

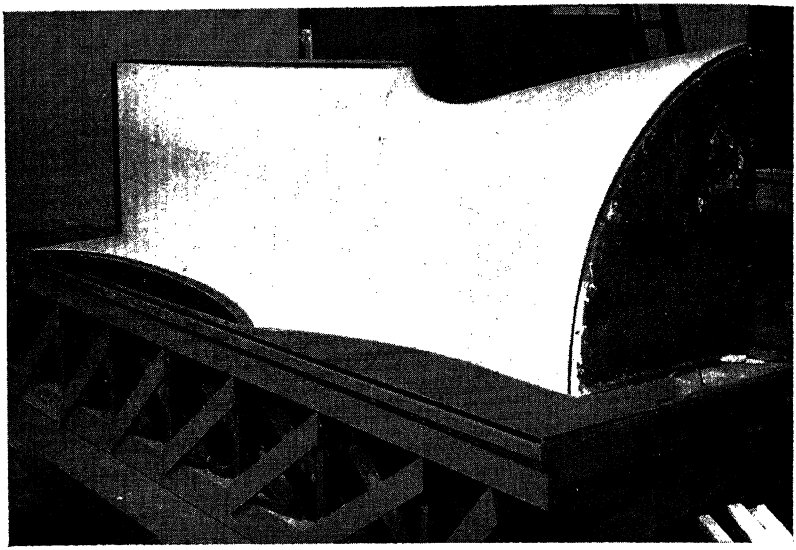


Fig. 2:17 Plaster Mock-Up of Intersection of Fin and Rudder with Fuselage

2:23 Form Blocks.

A form block is a block of suitable material made to the inside dimensions of formed parts to be produced, taking into consideration the forming characteristics of the metal to be worked.

Any material capable of withstanding high pressures without fracture or change of dimensions may be used. However, masonite, zince alloy, wood and steel are most commonly used. Steel is used for major hand forming, and for some hydro-press blocks. Zinc is often used where light hand forming is employed. Masonite is often used for a part that may be completely formed in the hydro-press. Masonite or wood may also be used for hand form blocks for parts, when only a few of such parts are required. Masonite does not split readily and blocks can usually be made from this material easier and cheaper than from zinc alloy or steel.

Block templates are used to determine the size of a form block. They are made to the inside dimensions of formed parts. Block templates indicate the shapes and contours of parts and may have information upon them such as direction of bends, (up or down), flange angles, etc. The amount of information placed upon the template varies with different manufacturers, many working on

the theory that a minimum amount of information is most desirable.

2:24 Punch Press.

A punch press generally consists of a bed or bolster and a mechanically operated ram which engages the punch, or male portion of a die, and forces it into the female portion of the die to shear out parts from stock or to form various parts from the **blank.** Airplane models change rapidly with the advance in aeronautical research. Consequently, the production of parts is rather limited. As a result, for economical reasons, the most commonly used die on the punch press is the continental die. The continental die, or temporary type, as it is sometimes called, is a low cost die that will suffice for a limited production, somewhere between 400 to a few thousand parts.

A more complex die is the compound die which performs more than one operation upon a part, but which does all the involved operations during one single stroke of the press ram. A representative compound die is the Blank, Pierce and Form Die which performs the operations of blanking, piercing, and forming in one operation of the die in order that all parts may be interchangeable.

2:25 Forming Operations.

Blank stock may be formed into parts of various shapes, contours, bends, and angles by hand forming or by the drop hammer, hydro press, power brake, etc. The difference between the hand forming of metal and forming by the other methods given above is that by hand forming the metal is gradually rolled into shape by beating with a wedge shaped fiber mallet, whereas it is pressed, or formed into shape in one operation by the machines.

2:26 Drop Hammer.

A drop hammer consists of a stationary bed or anvil and a heavy hammer head, see Fig. 2:20. The punch is attached to the hammer head, which is guided into the die secured to the anvil. The hammer head is freely dropped or in some cases slightly retarded to form the part from blank stock which has been placed on the die. Drop hammer dies are checked for proper contour by contour templates.

Typical examples of drop hammer work are cabin doors, wing corrugations, fairing, tank shells, etc. Materials which may be formed by the drop hammer are aluminum 2S½H and 3SO, Alclad 17SO and 24SO, extra deep drawing steel, stainless steel, and Inconel.

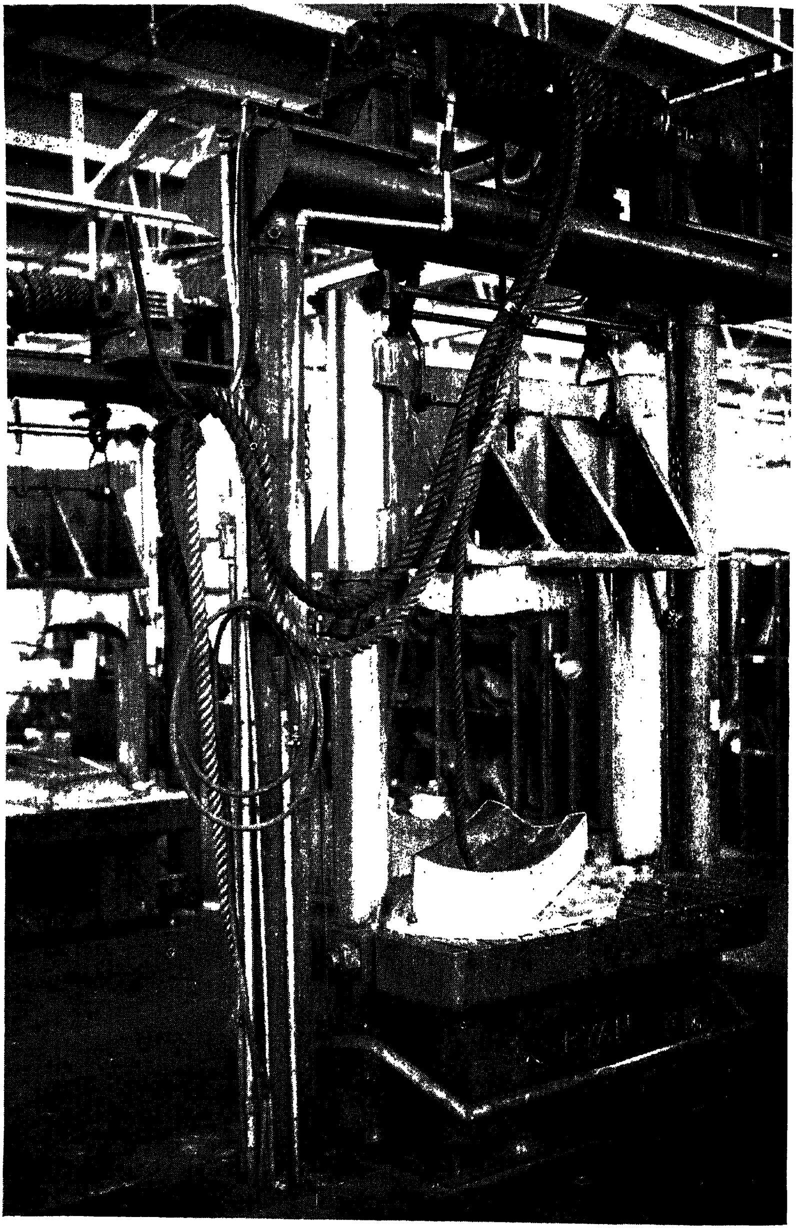


Fig. 2:20—Drop Hammer

2:27 Hydro-Press.

The hydro-press, as used in aircraft factory production of sheet metal parts, is a large slow-action forming machine operated by means of hydraulic pressure, ranging from 2000 to 5000 tons (approx.). In general terms, the machine consists of a large hydraulic cylinder which actuates a heavy flat ram having a large face area. The base of the machine supports a large flat **platen,** approximately equal in area to that of the face of the ram. See Fig. 2:22. In operation, a series of flat steel, masonite, or zinc alloy form blocks are placed on the platen. Metal parts to be formed are located on top of each form block and a heavy layer of rubber

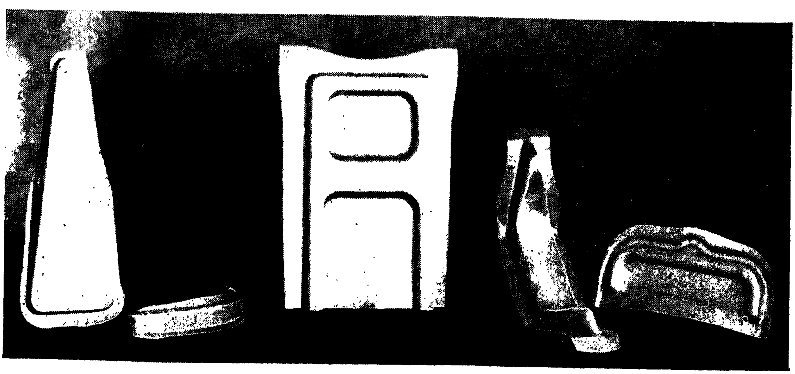


Fig. 2:21 (a and b)—Parts Made by the Drop Hammer

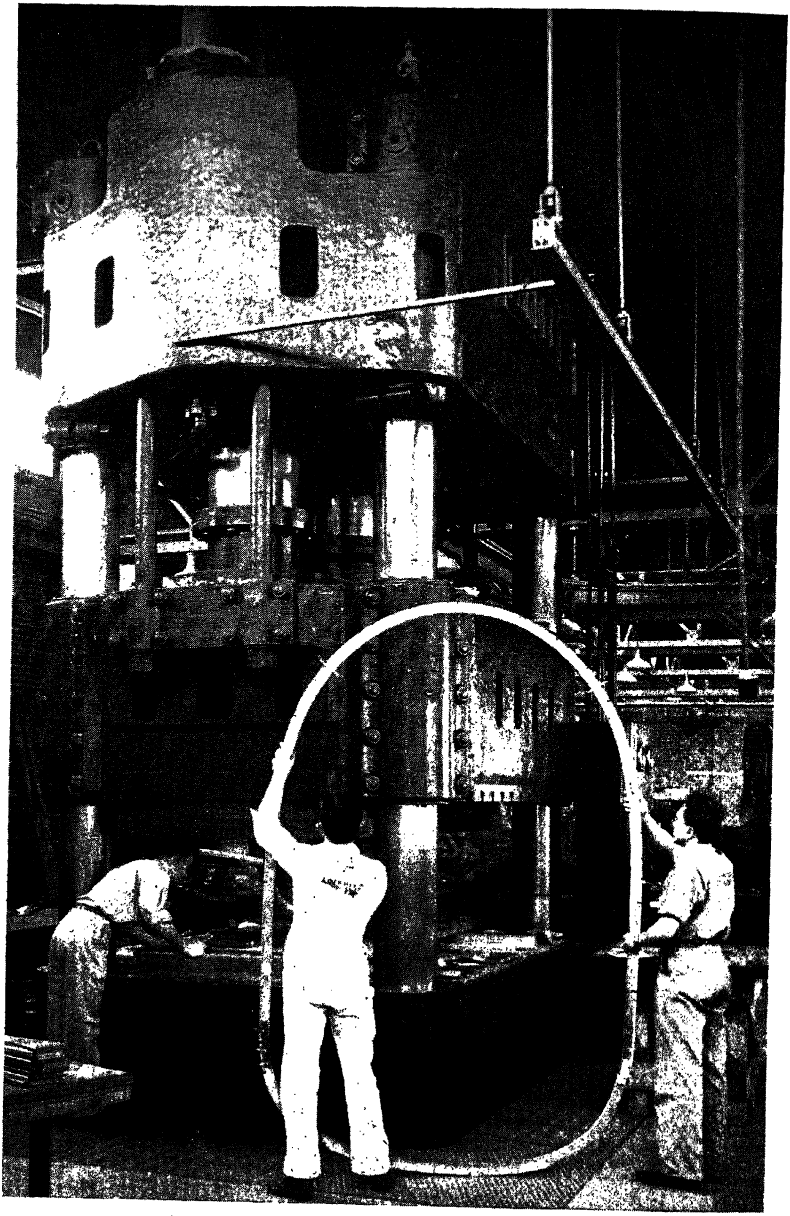


Fig. 2:22—Hydraulic Press and Airplane Bulkhead Frame that has been formed by the above hydro

blankets is placed over the group. As pressure is applied to the ram, the rubber forms the metal over the form blocks.

The principle advantage of this method of forming is the relatively low cost of making the tools for producing the part. Another is that comparatively little time is required to make the form blocks. The parts are unmarked by the rubber. A wide variety of parts may be formed simultaneously. Another forming machine is the power brake, consisting of a bolster and a ram. The power brake differs from the hand or leaf brake in that it utilizes a male and female die made of tool steel. A typical operation on the power brake is the forming of wing corrugations from flat stock.

2:28 Cutting Operations.

The cutting of sheet metal is accomplished by the use of any one or combination of the following tools: bandsaw, table saw, power shear, nibbler, unishear, flycutter, and the router.

The router is a machine using a vertical rotary cutting tool. It is mounted on a large swinging arm, and is used to cut several thicknesses of metal at one time. Router templates are used as guides in cutting out the parts.

2:29 Aluminum and Aluminum Alloys.[4]

Aluminum and its alloys constitute the principle structural material for use in the construction of the airplane. Of all the raw metallic materials used in the fabrication of the airplane, excluding engines, accessories, and other items of equipment, the aluminum alloys constitute over nine-tenths of the weight of the airplane. Aluminum and its various alloys are available in only two basic forms, wrought alloys and cast alloys. The cast condition is produced by heating the material to the melting temperature, pouring into suitable molds, and cooling to room temperature. The wrought condition is always derived from the cast condition and is produced by heating the cast ingot to a temperature of approximately 850°F. and reshaping by rolling, forging, or extruding while in the hot condition. The hot rolling, forging or extruding process breaks up the grain structure and produces a material possessing more desirable physical properties than can be obtained in the cast condition. They may then be rolled while hot down into smaller bars and rods or into sheets. Cast ingots may be heated and placed into an extruding chamber and forced through an orifice to produce any desired extruded

[4] Excerpt from Baughman's Aviation Dictionary & Reference Guide.

shape. The extruding process likewise breaks up the cast structure and produces a wrought condition of the material.

Certain of the aluminum alloys are used in the cast condition. For aircraft use these castings are either made in steel dies (die castings) or are cast in sand molds (sand castings). A modified form of the sand casting has been developed, known as the precision or Antioch casting. Die castings are never used for highly stressed or primary structural parts, because of their relatively poor internal structure due to porosity. Most die castings are not heat treated and for this reason are generally never made from heat treatable alloys. Recent development in the art of die casting has resulted in the ability to control the areas affected by porosity by confining these areas to locations in the rough casting which are to be machined out; for this reason the use of the die casting alloys in the more important applications is increasing. The most common die casting alloys used in aircraft are Alcoa alloys 13, 43, and 85. Since sand castings are used for structural applications they are generally made from heat treatable alloys such as Alcoa alloys 195, 220 and 356. Alloy number 43 is non-heat treatable, but is sometimes sand cast. No. 43 alloy gives a very dense, nonporous, weldable casting. The heat treatable sand castings are assigned a heat treatment designation of T4 or T6 dependent upon whether the casting has been artificially age hardened after solution heat treatment. Alloy 220 is not susceptible to artificial age hardening after solution heat treatment and hence is available only in the 220-T4 condition.

The permanent mold, which is a semi-precision method of casting, is increasing in use and is permitted in structural applications. Permanent mold castings are normally produced from the same types of alloys used for sand casting but with slight modifications in analysis to improve their pouring qualities.

The wrought aluminum alloys may be divided into two classifications: (1) strain hardening, (2) heat treatable. The Aluminum Company of America has assigned the letter S to designate the wrought alloys. The symbol is always used in connection with the Alcoa Number to designate the wrought alloys, regardless of whether they are the strain hardened or the heat treatable alloys.

The strain hardened alloys do not lend themselves to heat treatment. Their physical properties can be increased only by cold work and not by heat treatment. Heat treatment (annealing)

would relieve the effects of strain hardening. All of the strain hardened alloys can be annealed; such annealing will produce the most ductile condition of the alloy. The symbol O has been assigned by the Aluminum Company of America to indicate the fully annealed condition of the wrought alloys. This applies to both the strain hardening and the heat treatable alloys. Thus SO indicates a wrought alloy fully annealed. Strain hardening is a relative designation, hence it must be qualified as to the degree of strain hardening. This has been done by using the symbol H. The hard temper designated H is defined by the tensile properties which result from the maximum amount of cold working which is commercially practicable to introduce into the metal. Tempers intermediate between the soft and the hard temper are produced by varying the amount of cold work. The tempers are designated by the fractional symbols ¼H, ½H, and ¾H, indicating an increase of the strength of the annealed alloy by the corresponding fraction of the spread between the soft SO and the hard SH tempers. The common strain hardening alloys used in aircraft are Alcoa alloys 2S, 3S, 4S and 52S.

The heat treatable wrought alloys are classified as those whose physical properties are improved by heat treatment. The symbol ST is used to designate the heat treated condition of the wrought alloys. Additional physical properties can be imparted to the heat treatable wrought alloys by strain hardening after heat treatment. The symbol R is used to designate such strain hardening after heat treatment. Thus SRT indicates a wrought alloy S, heat treated T followed by strain hardening R after heat treatment. The principle heat treatable wrought alloys used in aircraft construction are Alcoa alloys 14S, 17S, A17S, 24S, 25S and 53S. After heat treatment and full age hardening, these alloys take the ST temper designation. Certain of the heat treatable aluminum alloys fully age-harden within a few hours at room temperature after solution heat treatment while others do not attain their maximum physical properties unless artificially aged at an elevated temperature (usually from 300° to 350° F., depending upon the alloy). The symbol **W** is used to designate the 'as quenched" condition of the wrought alloys, which means that they must be artificially aged at an elevated temperature to bring them to the T condition. Alcoa alloys 53S and 61S are the most common alloys used in aircraft which are used in the "as quenched" condition—53SW and 61SW.

A symbol placed before the alloy number indicates that the

chemical properties have been modified from the basic alloy, thus A 17S indicates that the alloy is similar in chemical composition to 17S. In the particular instance of A 17S, less of the hardening agent (copper) is present than is used in 17S alloy.

2:30 Plain Carbon and Alloy Steels.

Although plain carbon and alloy steels constitute a comparatively small part of most modern airplanes, they have specific advantages over aluminum alloys for the design of some aircraft units.

The plain carbon steels have proven to be of great value in the construction of such non-structural units as ducts, air intakes, and fairings, etc. The main advantages of these steels, such as S.A.E.* 1010 Deep Drawing stock, are the splendid forming and welding characteristics, as well as the low cost of the material as purchased from the rolling mills.

Another type of plain carbon steel which is widely used in the industry is S.A.E. 1117. This is known as a "free-cutting" steel because of the ease with which it can be machined, and consequently is utilized in the design of many small machined parts.

The use of alloy steels in the design of vital fittings and precision machines is of paramount importance to the aircraft industry. Although steels in general have no structural advantages over the light metals such as aluminum or magnesium, a few of the many advantages that make them indispensible to the industry are given below.

Alloy steels may be obtained in a wide range of physical properties, thus permitting the use of the most desirable combination of properties for any particular application. Also, it is possible to produce surface hardnesses in excess of any of the other structural materials. These hardened surfaces permit the manufacture of such parts as ball bearings and gears, etc., which require great hardness combined with toughness. These properties also produce superior abrasion resistance, which is needed in the design of brake drums, cams, and latches. Steels lend themselves to a great variety of surface treatments all of which give them special surface qualities. These treatments may be in the nature of (1) case hardening, nitriding, or flame hardening, (2) electroplating, for wear resistance, corrosion resistance or appearance, or (3) chemical treatment for corrosion protection or as a paint base. The

*Society of Automotive Engineers.

melting points of most of the alloy steels are higher than those of the light alloys. Therefore, they can be used in places where fairly high temperatures must be resisted—such as engine exhaust stacks, etc. Also, the weldability of many of the high strength alloys allows their use in the design of such components as engine mounts and landing gears. One last factor of importance to emphasize is the high density of steels, which, when combined with their favorable strength-weight ratios and stiffness-weight ratios, permits the design of strong compact parts such as springs, cables, bolts, and ball bearings, etc.

REVIEW QUESTIONS

1. By what means may the template man keep abreast of aircraft developments and new nomenclature?
2. Name the control surfaces of an airplane and the action each gives to the airplane.
3. Discuss the lofting of a fuselage.
4. How are master contour templates developed?
5. What is a loft floor?
6. What is a body plan?
7. Define a mold line; buttock line; waterline; base line; tumble home; bend line; radius tab; tolerance.
8. What is bend allowance? Set back? Why are they used?
9. What is a jig? Name some special types and tell what they are used for.
10. What is a plaster mock-up? How is it made? How is it used?
11. What materials are used for form blocks for hand-forming and the hydro-press?
12. What determines the size of a form block?
13. Describe the continental die. How is it used?
14. What is the difference between the hand forming and machine forming of sheet metal?
15. How are drop hammer dies checked for contour?
16. What purpose does the rubber platen serve on a hydro press?
17. What methods are used for assembling aircraft sheet metal parts?
18. What are the principal heat treatable wrought alloys used in aircraft construction?
19. Define SO, ST, SRT, and ½ H.
20. What line is determined by the edge of a block template?

CHAPTER III.

MATHEMATICS FOR THE TEMPLATE MAKER

A very brief review of mathematics commonly used in template making with typical application:

3:1 Conversion of Fractions to Decimals.

It is often necessary to add together several dimensions which are expressed as fractions of inches. It is possible to add fractions by changing them all to a common denominator but this method is more difficult and much more subject to errors than the method of converting fractions to decimals.

There are numerous quick reading decimal equivalent conversion tables published which may be used to convert fractions to decimals or vice versa. If such a table is not available, it is helpful to know that any fraction may be converted into a decimal by dividing the numerator by the denominator, as for example: to change $^{13}/_{16}$ to a decimal, divide 13 by 16 to get .8125.

When the thickness of the metal is included in a series of dimensions to be added together the practice of reducing fractional dimensions to decimals allows the thickness to be added into the column very easily because sheet metal thicknesses are usually expressed as decimals: .040, .051, .025, etc.

3:2 Correct Fractions.

A fraction, to be correct, should always be in its lowest reduced form. For example, $^{4}/_{16}$ and $^{12}/_{32}$ are incorrect. Such fractions should be reduced to $^{1}/_{4}$ and $^{3}/_{8}$, respectively, by dividing both the numerator and denominator by the largest common divisor The prevalent use of rules on which the divisions are numbered in 16ths or 32nds has caused a certain amount of incorrect expression of fractions. These rules are faster and easier to read, but scale reading such as $^{8}/_{16}$ or $^{24}/_{32}$ should be expressed as $^{1}/_{2}$ and $^{3}/_{4}$.

3:3 Calculation or Areas.

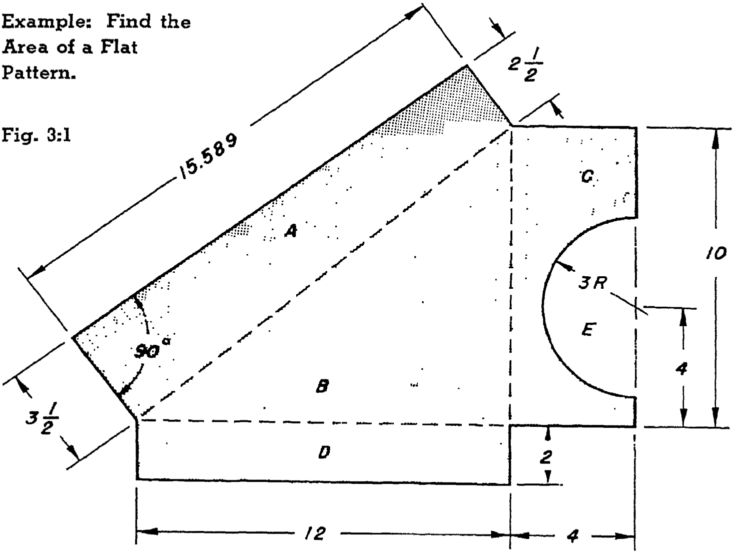
It is often necessary to find the area of shapes which cannot be covered by a single formula. Such shapes should be broken up into separate parts, each of which can be figured as a separate problem.

Fig. 3:1 clearly illustrates a typical problem and the solution. Each part is divided up into a conventional geometrical figure and

shows the area of each computed section. The results are then added for the answer.

Example: Find the Area of a Flat Pattern.

Fig. 3:1



To find Area of Trapezoid A : $A = \dfrac{(3.5 + 2.5 \quad (15.589)}{2} = \ldots\ldots\ldots\ldots$ ..46.767

To find Area of Triangle B : $B = \dfrac{\text{Base} \times \text{Height}}{2} = \dfrac{12 \times 10}{2} = \ldots\ldots$ ..60.000

To find Area of Rectangle C minus Circular cutout E:

$C = \text{Base} \times \text{Height} - \dfrac{\pi R^2}{2} = (4 \times 10) - \dfrac{3.1416 \times 9}{2} = 25.863$

To find Area of Rectangle D : $D = \text{Base} \times \text{Height} = 12 \times 2 = \ldots$ ..24.000

TOTAL AREA = sq. in.................................156.630

3:4 Trigonometry.

Trigonometry is used extensively in the shop, and template makers should be able to solve triangles easily by the use of trigonometry. There is nothing difficult or mysterious about trigonometry. It consists essentially of determining the unknown parts of triangles by using the known parts and the ratios which exist

between the parts. There are six parts in every triangle, three sides and three angles. When any three parts are known, provided one of them is a side, the other parts may be calculated.

Right triangles are triangles in which one of the angles is equal to 90°. Right triangles are much simpler to solve than other triangles. A problem which involves a triangle which does not contain a 90° angle may be solved rather simply by dividing the original problem into two or more right triangles.

The following discussion will concern right triangles only.

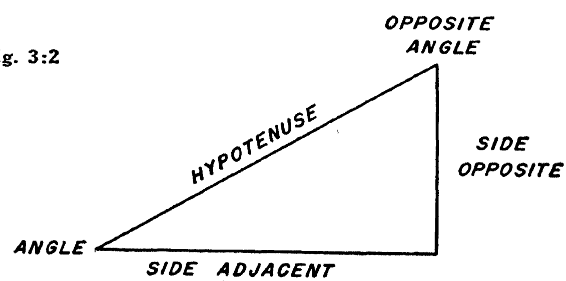
In a right triangle, the 90° angle is of course known, so in order to solve the unknown elements, it is necessary to know only two other parts, either a side and an angle or two sides. In a right triangle the sides and the ratios between the sides are given names. The sides and their ratios are names according to their position with respect to one of the acute angles which will hereafter be called **the angle.** The side opposite the angle is called "side opposite." The side opposite the 90° angle is called the "hypotenuse" and is always the longest side. The side, which with the hypotenuse forms the angle, is called the "side adjacent." See Fig. 3:2.

The ratio of the side opposite to the hypotenuse is called the sine of the angle. There are five other ratios between the sides of a right triangle; cosine, tangent, cotangent, secant, and cosecant. These ratios are called trigonometric functions.

The statement that the sine of the angle is the ratio of the side opposite to the hypotenuse can be written as a formula or equation:

$$\text{Sine of the angle} = \frac{\text{side opposite}}{\text{hypotenuse}}$$

Fig. 3:2



Ratios between the sides that give the other trigonometric functions are as follows:

$$\frac{\text{Side adjacent}}{\text{Hypotenuse}} = \text{Cosine of the angle}$$

$$\frac{\text{Side opposite}}{\text{Side adjacent}} = \text{Tangent of the angle}$$

$$\frac{\text{Side adjacent}}{\text{Side opposite}} = \text{Cotangent of the angle}$$

$$\frac{\text{Hypotenuse}}{\text{Side adjacent}} = \text{Secant of the angle}$$

$$\frac{\text{Hypotenuse}}{\text{Side opposite}} = \text{Cosecant of the angle}$$

These six relations should be memorized by the student.

For a given angle, the ratio of side opposite to hypotenuse has a certain value; for example, if the angle is 20° the ratio is .3420, or:

$$\text{Sin } 20° = .3420$$

This equation is true regardless of the size of the triangle because as long as the angle is the same, the **ratio** of the sides will not change. But, when the angle changes, the ratio of the sides changes and so the sine changes; for example:

$$\text{Sin } 21° = .3584$$

The cosine, tangent and other trigonometric functions are similar to the sine in that the value of each varies as the angle varies. Tables of natural values of Trigonometric Functions usually show the values of only the four most important functions, sine, cosine, tangent, and cotangent. If values of the secant and cosecant are desired, they can be found from the following relations:

$$\text{Secant} = \frac{1}{\text{cosine}}$$

$$\text{Cosecant} = \frac{1}{\text{sine}}$$

Formulas for finding the length of sides for right angle triangles when an angle and side are known:

$$\text{Length of Side opposite} = \begin{cases} \text{Hypotenuse} \times \text{Sine} \\ \text{Hypotenuse} \div \text{Cosecant} \\ \text{Side adjacent} \times \text{Tangent} \\ \text{Side adjacent} \div \text{Cotangent} \end{cases}$$

Length of Side adjacent	=	(Hypotenuse × Cosine (Hypotenuse ÷ Secant (Side opposite × Cotangent (Side opposite ÷ Tangent
Length of Hypotenuse	±	(Side opposite × Cosecant (Side opposite ÷ Sine (Side adjacent × Secant (Side adjacent ÷ Cosine

Care must be exercised in looking up values in trigonometry tables because mistakes are easily made. Ability to use the tables may be checked by verifying the following values:

$$\begin{aligned} \text{Sin } 77^\circ\ 30' &= .9763 \\ \text{Cos } 29^\circ\ 15' &= .8725 \\ \text{Tan } 56^\circ\ 40' &= 1.5204 \end{aligned}$$

To demonstrate the use of trigonometry tables in solving a triangle, suppose that a right triangle has a 20° angle and that the side adjacent is 14″. What is the length of the hypotenuse and of the opposite side?

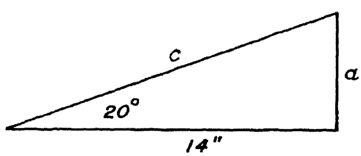


Fig. 3:3

In the triangle in Fig. 3:3, the adjacent side (14″) and the angle (20°) are known. So to find the hypotenuse "c" the following equation can be written:

$$\frac{14}{c} = \text{Cos } 20^\circ$$

Solving this equation for "c":

$$c = \frac{14}{\text{Cos } 20^\circ}$$

The trigonometry table shows that Cos 20° = .9397

then $c = \dfrac{14}{.9397}$ or 14.89″

To find the opposite side "a", the following equation may be used.

the adjacent side being 14″, the angle 20°, and the unknown opposite side "a":

$$\frac{a}{14} = \tan 20°$$

$$\text{or} \quad a = 14 \times \tan 20°$$

The trigonometry tables show that tan 20° = .3640

$$\text{then} \quad a = 14 \times .3640 = 5.096''$$

To take another example, suppose a right triangle has a side 15″ and a side 18″. What is the angle adjacent to the 18″ side? (Fig. 3:4.)

Using the known sides and the angle being sought, the following equation is written:

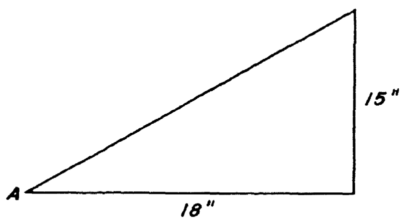


Fig. 3:4

$$\tan A = \frac{15}{18} = .8333$$

Looking up .8333 in the tangent column in the table of trigonometric functions, shows that .8333 is the tangent of angle 39° 48′ which is the angle being sought.

In addition to the use of tables of trigonometric functions, the following rules are sometimes helpful in solving for parts of triangles:

1. In a right triangle, the sum of the squares of the short sides always equals the square of the hypotenuse. So if the lengths of two sides of a right angle triangle are known, the third may be found by using the equation.

a^2 plus $b^2 = c^2$ where "a" and "b" are the short sides and "c" is the hypotenuse.

2. In any triangle the sum of the three angles always equals 180″. So if two angles are known the third can be found by subtracting the sum of the two known angles from 180°.

3:5 Examples of Practical Application of Trigonometry

1. Frequently it is difficult or impossible to measure an angle accurately with a protractor. In many such cases the angle can be accurately calculated by trigonometry.

Fig. 3:5 shows the construction used. If "a" is the angle to be measured, lay off a convenient distance A C (say 10") along one side of the angle and at "C" erect a perpendicular to form a right triangle ABC. Next, measure distance B C. then:

$$\tan A = \frac{BC}{10''}$$

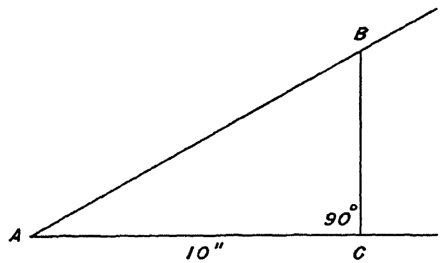


Fig. 3:5

By looking up the value of $\frac{BC}{10}$ in the tangent column in the table of trigonometric functions, the angle "A" can be found.

This method can also be used to construct or lay out various angles. To construct an angle "A" measure off AC = 10" along the line from which the angle is to be laid off, beginning at "A", the point where the angle is to start. Then erect a perpendicular at "C". Next, look up the tangent of angle "A".

$$\text{Since} \quad \tan A = \frac{\text{side opposite}}{AC} = \frac{\text{side opposite}}{10''}$$

$$\text{opposite side} = 10 \times \tan A$$

Therefore lay off on the perpendicular, a distance BC equal to 10 times the value of tan "A". Then a line drawn from "A" through "B" will make an angle "A" with AC.

In using this method to measure or construct angles, all measurements should be made very carefully and the perpendicular erected accurately. A 10" base is used because it makes the calculations very simple, but if necessary a longer or shorter base can be used. When a series of holes are spaced around a circle, the spacing is often specified as so many holes equally spaced.

By trigonometry, it is possible to find out what the straight line distance between the centers of adjacent holes should be in such cases. The spacing of the holes can then be easily checked by scale measurements.

Fig. 3:6

2. Five holes equally spaced on 10″ diameter circle.

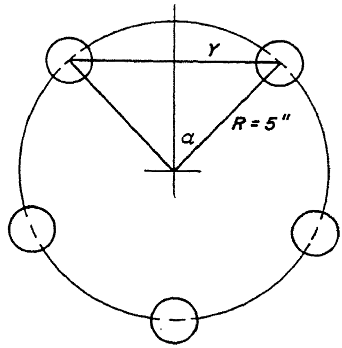


Fig. 3:6 shows the construction used. In solving a problem of this kind, it is not necessary to make an accurate layout because no measurements are involved. A rough sketch will be sufficient to show the trigonometry to be used. First a triangle is drawn between the center of the circle and the centers of two adjacent holes. Then this triangle is divided into two right triangles by a line bisecting the angle between the holes. Now "Y" is one-half of the distance being sought and "Y" can be found by solving the right triangle in the following steps:

Angle "a" = ½ the angle between holes

and: Angle between holes $= \dfrac{360°}{\text{number of holes}}$

therefore: angle "a" $= \frac{1}{2} \times \dfrac{360°}{\text{no. of holes}} = \dfrac{180°}{\text{no. of holes}}$

$$a = \frac{180°}{5} = 36°$$

The hypotenuse of the triangle is "R" which, being the radius of the circle is always known. With both "a" and "R" known, it is possible to find "Y" from the equation:

$$\text{Sin a} = \frac{Y}{R}$$

or: $Y = R \times \text{Sin a} = 5 \times \text{Sin } 36° = 5 \times .5878 = 2.9390''$
then distance sought $= 2Y = 5.8780''$

This solution can be written as a single equation which can be used to solve any hole spacing problem.

$$\text{Straight Line Distance between holes} = 2R \times \text{Sin}\,\frac{180°}{\text{no. of holes}}$$ [5]

3. Drawings of parts sometimes show dimensions in such a way that the part cannot be checked except by elaborate layout work. Sometimes, in such cases, the template maker can use trigonometry to calculate dimensions by which the part can be checked by direct measurement. Fig. 3:7 shows an example of this.

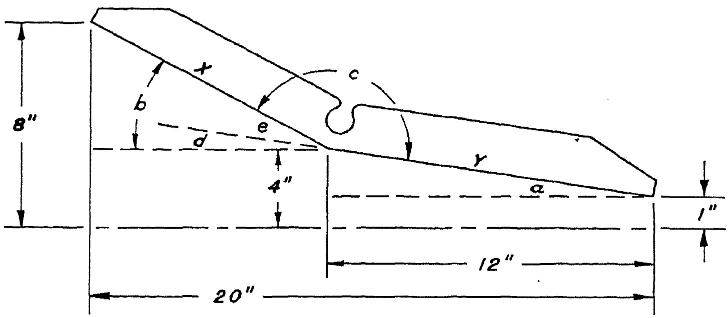


Fig. 3:7

A special set up would be required to check this part using the dimensions shown. But if distances "X" and "Y" and angle "c" were known the part could be easily checked with a scale and protractor. By forming triangles as shown by the dotted lines, distances "X" and "Y" can be determined by trigonometry.

Angle "c" is equal to 180° minus the difference between angles "a" and "b". This can be written as: c = 180° — (b — a).

This can be proved as follows: By extending line "y" to the left to form angles "d" and "e" as shown in Fig. 3:7 it can be seen that:

c = 180° — e
and that..............e = b — d
but.........................d = a (Parallel lines cut by a transverse line)
therefore..............e = b — a

The rest of the problem is left for the student.

[5] Although this method is theoretically correct, the template maker soon discovers that the most practical way to divide a circle into an even number of parts is by trial and error.

Fig. 3:8. Wood Hand Form Block

CHAPTER IV.

ELEMENTARY DRAFTING

4:1 General.

The purpose of this and the following chapter is to develop the ability to understand and write the universal language of the draftsman and engineer. To develop the ability both to express one's thoughts on paper in the form of drawings and to interpret the thoughts of others expressed in the same manner.

This involves becoming familiar with fundamental principles of geometry, projection and mathematics. Taken step by step, from examples involving first one principle, then two and so on, steadily building brick by brick as we go, we can accomplish much. Learning the single principles thoroughly, finding and using practical applications will impress them firmly on your mind so that they become useful tools, always available for use.

An airplane is a complicated structure, but essentially only an assembly of simple parts, rivets, bolts, stringers, bulkheads, ribs, sheet stock, etc. Taken unit by unit, the airplane becomes understandable though still in its entirety a complicated structure. So it is with drawings. While in many cases apparently complicated, yet line by line, surface by surface, unit by unit, the drawing becomes intelligible and simple. It is from this point of view that we mean to attack the problem, establishing the simple principles, assembling them as we go, and visualizing the parts and the whole in the proper relation to each other.

4:2 Drawing Instruments and Supplies.

The drawing board is a flat, smooth surface for holding the paper while drawing is being made. One edge is used as a straight edge to guide the T-Square. Drawing boards are usually made of white pine or a similar soft, smooth grained wood. For the purpose of this course, a drawing board measuring approximately 14" x 20" or larger is convenient. This will accommodate 8½" x 11" (size A) and 11" x 17" (size B) drawings.

The drawing paper should be a high grade paper with good erasing qualities. Scotch tape, thumb tacks, or staples may be used to secure the paper to the board. It is general practice to place the paper so that the upper edge is parallel to the upper edge of the board. This may be accomplished by adjusting the

paper so that its upper edge coincides with the upper edge of the T-Square before tacking it to the board.

Standard type of drawing pencils should be used in preference to writing pencils as the lead is of a higher grade, and is generally of a more consistent quality. A 5 H is recommended for layout of construction lines, and a 2 H for lettering, sketching and detailing. Many draftsmen prefer the mechanical type of drafting pencil with an adjustable or changeable lead.

Pencils should be sharpened with a knife or a special drafting pencil sharpener. In both cases the wood should be removed leaving the whole lead. After about 1/4" of lead is exposed, it may be pointed with a fine single cut file or a sandpaper pad. Conical points are recommended for pointing, sketching and lettering, whereas chisel points are used for straight lines, where accurate work is essential, e.g., stress diagrams, etc., the flat head of the lead being held parallel to the straight-edge.

4:3 T-Square.

The T-Square consists of a long piece called the blade, and a shorter piece at right angles at one end called the head. Unless a person is left handed, the head of the T-Square is always applied to the left side of the board. The inner edge of the head and the upper edge of the blade are the working edges of the T-Square. For accuracy in work they must be smooth and straight. A T-Square may be checked by placing it in a working position with the head firmly against the straight edge of the drawing board and drawing a line along the entire length of the blade.

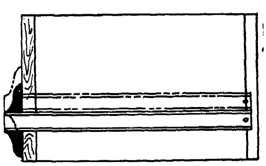


Fig. 4:1
Checking T-Square

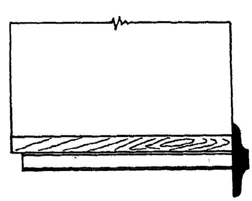


Fig: 4:2
Checking Straight Edge of a Drawing Board

The T-Square is then turned over and a line drawn along the same edge. If the lines coincide, the T-Square is true. If not, the error is half that of the interval shown between the lines.

If the working edge of the T-Square is found to be true, the straight-edge of the drawing board may be checked by laying the working edge of the T-Square along the straight-edge of the board. If the straight-edge is true, no light cracks will be seen between the edges of the T-Square and the board.

The T-Square is used for drawing horizontal lines with the working edge of the head firmly against the straight-edge of the board. In general, lines should be drawn from left to right with the pencil held firmly against the upper edge of the T-Square.

4:4 Drafting Triangles.

Drafting triangles are celluloid right triangles with complementary angles of 30° - 60° and 45° - 45°. Vertical lines and inclined lines are drawn with the right triangles, using the T-Square as a guide. Vertical lines are usually drawn from bottom to top of the board with the vertical edge of the triangle towards the left edge of the board. Various combinations of the angles and the T-Square will provide angles of 15°, 30°, 45°, 75° and 90°.

Triangles will occasionally warp out of square through use. To check how square the 90° angle of a triangle is, place the triangle against the working edge of a T-Square that has been checked. Draw a vertical line, then turn the triangle over and draw another line along the same edge. If the lines coincide, the triangle is square. If not, the error is half of the interval between the lines.

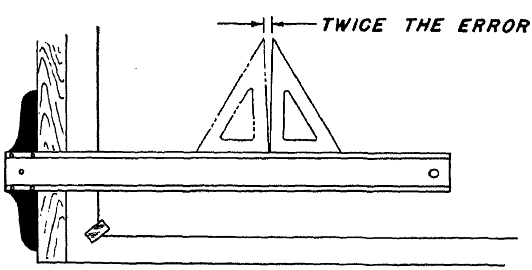


Fig. 4:3—Checking a Triangle

Inclined parallel lines may be drawn by using two triangles placed with one edge of each against the other. With the tri-

angles so placed, the edge of one triangle can be made to coincide with the given line. Parallel lines may then be drawn at intervals by sliding the triangle, with one edge parallel to the given line, along the guiding triangle.

4:5 Protractor.

The protractor is a semi-circular celluloid instrument graduated in degrees (generally through 180 degrees). The special type of protractor shown in Fig. 7.9 is preferably used in the template shop for the layout of angles.

4:6 Rules.

A rule in general terms is a flat strip of wood, metal, celluloid, or plastic material, having straight edges indexed or graduated in suitable distance units for the purpose of measuring full or natural sizes of an object. Most rules used in the shop are the flexible or semi-flexible type, having lengths of 6 or 12 inches. Although in many cases, especially in loft work, the 18 or 24 inch rule is very convenient. The graduations on these rules are in halves, quarters, eighths, sixteenths, thirty-seconds and sixty-fourths of an inch.

Quick Reading Rule: A quick reading rule (sometimes called fast reading) is one having the sixty-fourths and thirty-seconds added and the numerical total stamped at regular intervals along the length of each inch division. This system of marking saves time, decreases eye strain and has the possibilities of decreasing errors in measuring.

Decimal Rule: As the name implies, this rule is graduated in decimal parts of an inch, and is a valuable rule for use in layout of templates because many shops require that dimensions be in decimals (thousandths).

4:7 Scales.

It is not always possible to draw objects to their true or full size, so they must often be drawn to uniformly reduced dimensions by the use of scales.

A scale is similar to a rule in that it is a straight edged piece of wood, metal, celluloid or plastic, etc., graduated in some regular divisions. It differs from a rule, however, in that whereas a rule is graduated in direct full scale measuring units, the scale is graduated so as to indicate or represent measurements for

making reduced or increased scale (reduced or increased size) of an object.

There are two general types of scales, (1) the mechanical engineers scale, which is sometimes referred to as the Architects' scale, and (2) the civil engineers scale. The mechanical engineers scale is used on machine and structural drawings and is divided into proportional feet and inches, e.g., 6″ = 1′ (half size), 3″ = 1′ (quarter size), 1½″ = 1′ (eighth size), ½″ = 1′ (twenty-fourth size), etc. The civil engineers scale is graduated in tenths of an inch and is used for map making, plotting, graphs, drawing stress diagrams, etc. This scale enables an engineer to read dimensions of less than an inch in 10ths and also scale load diagrams in tenths. Modern engineers are now beginning to use a decimal scale graduated in thousandths.

There are two general types or forms of both the architects scale and the civil engineers scale; (1) the triangular scale (triangular cross section) which has ten of the most commonly used scales on its sides, and (2) the flat scale, which as the name implies is a flat scale with fewer scales on its sides than the triangular scale. Obviously a greater number of flat scales will be required than the triangular form, but many draftsmen prefer to use the flat scale because it is much more convenient to use and there is less lost time due to the fact that the triangular scale has too many scales on the same stick. When chosing a flat rule, be sure to choose one that is easy to pick up.

In summation, we might add that rules are used in the shop and scales are used in the engineering or drafting rooms. An added note of caution is well worthwhile, namely, do not use a wooden rule for drawing lines, do not handle any rule or scale in such a manner as to mar the straightness of the graduated edges and where graduations start at the extreme end of a rule or scale, do not start a measurement from the end because a small portion of the end may we worn or inaccurate.

4:8 Compass.

A compass is an instrument consisting of two legs hinged together, one having a pin point and the other a pencil or pen part. For circles with large radii, a lengthening bar may be inserted into the pencil leg. The pencil point should be beveled on one side in such a way that the flat face always faces out

from the center of the circle. This is necessary in order to get a sharp clear line. A 5 H lead is often used.

4:9 Dividers.

Dividers are similar in design to a compass with the exception that both legs are provided with pin points. Transfer of dimensions from the scale to the drawing, dividing of lines into equal parts, and transferring lengths of lines from one point to another on a drawing are functions of the dividers.

4:10 Bow Instruments.

Bow instruments are small compasses having a screw arrangement which accurately spaces the legs. They are used in the same manner as the compass and divider. The legs are under spring tension making it possible to draw precise arcs or circles. Bow instruments are generally used for radii of one inch or less. For faster work and less wear on the threads, it is advisable to compress the legs of a bow instrument, while resetting it, thus relieving the pressure on the nut.

4:11 Irregular Curves.

Irregular curves may be drawn with a **spline,** or what is commonly called a French Curve. French curves are usually made of celluloid, and are made in a variety of shapes covering a wide range of curves.

In drawing a curve, the line is first plotted with a series of points. Next, the French Curve is adjusted until one of its many curves coincides with three or more points. All but the extreme points covered are included in a line drawn against the edge of the curve. Not more than three points should be connected at one time.

4:12 Geometrical Construction.

The following examples of geometrical constructions are intended to acquaint the student with the problems that will be met in template layout and drafting. No mathematical proofs are given as they may easily be found in the many text books on plane geometry. The template maker, however, should become sufficiently familiar with plane geometry to be able to apply its principles to the solution of layout problems.

4:13 To Draw a Line Parallel to a Given Line at a Given Distance.

Given: Line A B Distance C-D

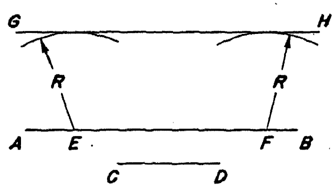


Fig. 4:4

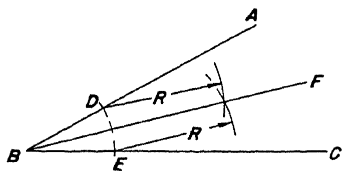
Construction:

With R equal to CD, and any two centers such as E and F, draw two arcs. G H drawn tangent to both arcs is parallel to A B.

4:14 To Bisect an Angle.

Given: Angle ABC

Fig. 4:5

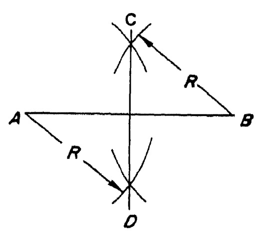


Construction: With B as a center, strike an arc cutting AB and CB at D and E respectively. With D and E as centers and a radius R, draw two intersecting arcs. BF bisects angle ABC.

4:15 To Construct the Perpendicular Bisector of a Line.

Given: Line AB

Fig. 4:6

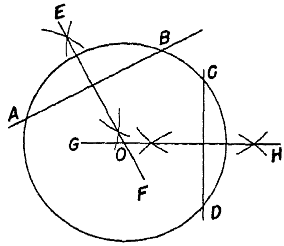


Construction: With A and B as centers and radius R greater than one-half AB, construct 2 intersecting arcs above and below AB. CD is the perpendicular bisector of AB.

4:16 To Find the Center of a Circle.

Given: A circle

Fig. 4:7



Construction: Draw two chords, AB and DC. Construct the perpendicular bisectors EF and GH of AB and DC respectively. Intersection O is the center of the given circle.

4:17 To Pass an Arc with a Given Radius Through Two Given Points.

Given: Points A and B
Radius R

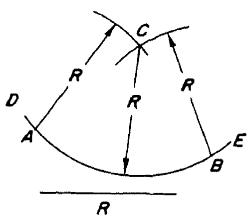


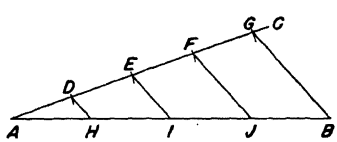
Fig. 4:8

Construction: With A and B as centers and R as radius, swing two arcs. With intersection C as center and R as radius draw arc DE, which will pass through A and B.

4:18 To Divide a Line into Any Number of Equal Parts.

Given: Line AB to be divided into 4 equal parts.

Fig. 4:9



Construction: Draw AC at an acute angle to AB. With a compass or divider, mark off 4 equal segments of convenient length, AD, DE, EF, and FG on the line AC. Draw GB. Construct FJ, EI, and DH parallel to GB. AB is divided into 4 equal parts, AH, HI, IJ, and JB.

4:19(a) To Draw a Pendicular from a Point to a Line.

Given: Point "P" and line AB

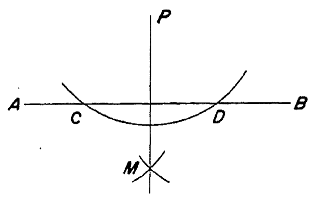


Fig. 4:10

Construction: Swing an arc from P to intersect AB at C and D. From C and D, swing equal arcs to intersect at M. PM is desired perpendicular.

4:19(b) To Construct a Line Perpendicular to Another Line, at Its End.

Given: Line AB.

Construction: Using any size radius from any point "P" swing an arc which will intersect line AB at A and any point between A and B such as "C", continue the arc until it is above A. Draw a straight line through points C and P until it intersects the arc at E. Line EA is perpendicular to line AB.

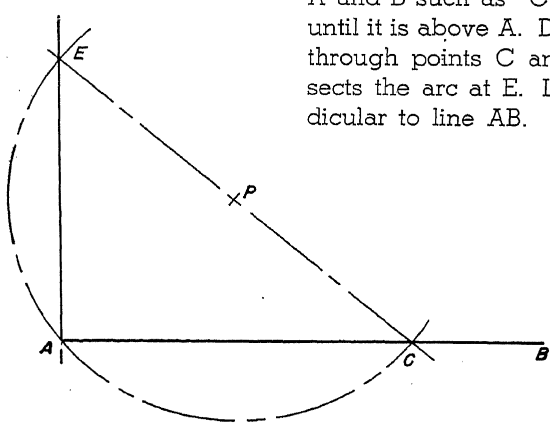
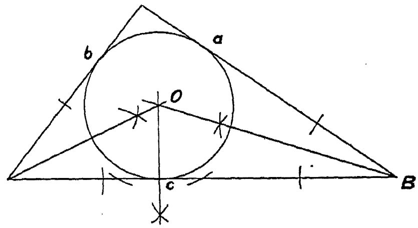


Fig. 4:11

4:20 To Inscribe a Circle in a Triangle.

Given: Triangle ABC

Fig. 4:12

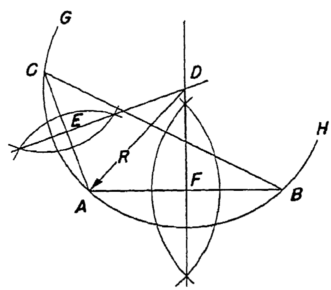


Construction: Bisect any two angles, for example, angle A and angle B. From O construct a line perpendicular to any one side of the given triangle, such as Oc. With Oc as a radius and point O as a center, draw the circle which is tangent to sides a, b, c.

4:21 To Circumscribe a Circle about a Triangle.

Given: Triangle ABC

Fig. 4:13



Construct perpendicular bisectors DE and DF to chords CA and AB respectively. With D as a center and DA as a radius, swing circle GAH.

4:22 To Draw a Circular Arc of Given Radius Tangent to Two Non-Parallel Lines.

Given: Non-Parallel Lines AD and CB
Radius R

Construction: With R as a distance, construct EF and GF par-

allel to AD and CB respectively. With intersection F as a center and R as a radius, describe arc HI. HI is tangent to CB and AD.

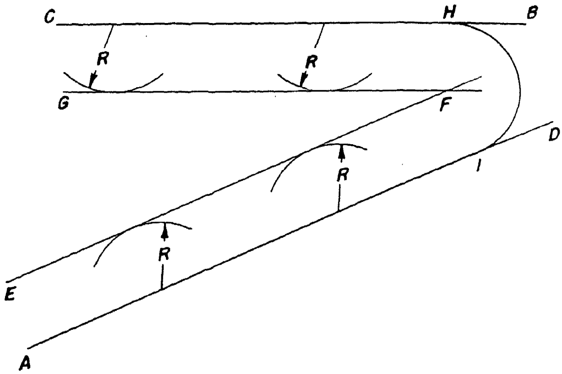
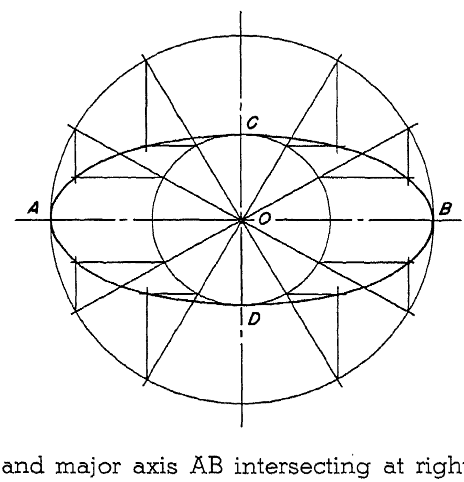


Fig. 4:14

4:23 To Draw an Ellipse by the Concentric Circle Method.

Fig. 4:15



Given: Minor axis CD and major axis AB intersecting at right angles at point O.

Construction: With O as a center and OC as radius, describe a circle. Likewise with radius OA, describe a concentric circle. Next divide the circles with a number of diameters. With T-Square and triangle draw horizontal lines from intersections of the diameters with the smaller circle, and vertical lines from intersections of the diameters with the larger circle. The intersections of the

horizontal and vertical lines thus drawn are connected to complete the ellipse.

4:24 Ellipse, Trammel Method.

Fig. 4:16 illustrates the method of drawing an ellipse by use of trammel points. The details of the method consist of setting two points of the trammel at a distance A′O′ apart which is equal to one-half the major axis and D′O′ equal to one-half the minor axis. Move the trammel points in such a manner as to keep A′ on the minor axis and D′ on the major axis. The point O′ will trace the ellipse.

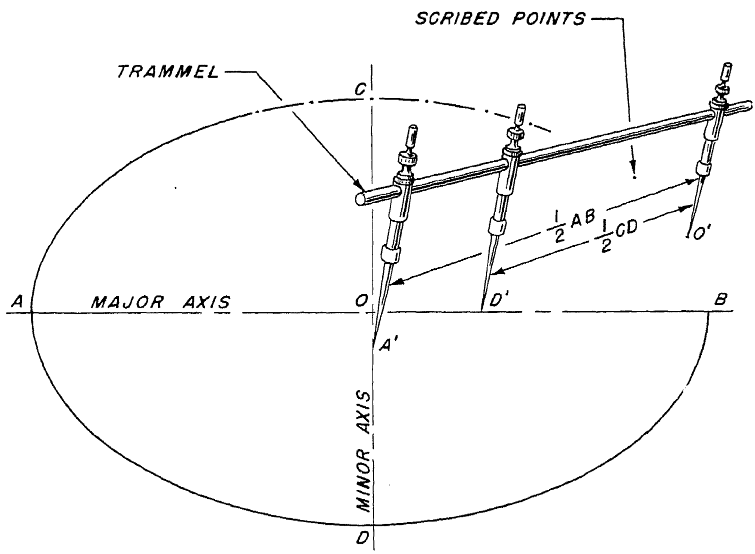


Fig. 4:16

4:25 Regular Polygons.

Regular polygon is the term applied to a geometric figure with all of its sides equal and all of corresponding angles between these sides equal. The primary regular polygons are: equilateral triangle, 3 sides; square, 4 sides; pentagon, 5 sides; hexagon, 6 sides; heptagon, 7 sides; and octagon, 8 sides.

Construction of regular polygons:

Equilateral triangle:

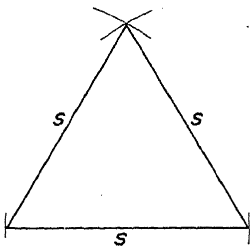


Fig. 4:17

Pentagon:

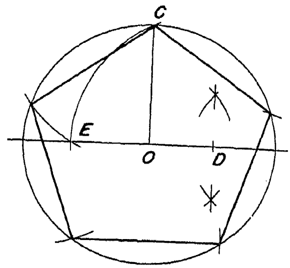


Fig. 4:18

From the limits of s, swing intersecting arcs of length s.

Pentagon:

To inscribe a pentagon in a circle. Fig. 4:18. Draw the diameter of the circle and radius OC perpendicular to it. Bisect one-half of the diameter. With this point D as center and a radius DC draw arc CE. With center C and radius CE, draw arc intersecting the circle. A line from C to the intersection is one side of the pentagon. Using this length, step off on the circle the other sides of the pentagon.

Hexagon:

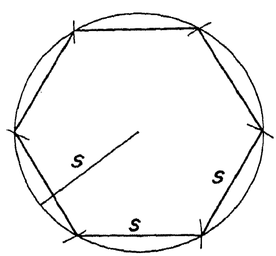


Fig. 4:19

Given: The length of one side of a hexagon.

Construct a circle with radius equal to the side of the given hexagon.

Step off chord distances on the circle equal to radius (s).

GEOMETRIC CONSTRUCTION PROBLEMS

In the following problems, show all construction lines.

1. Bisect the angle.

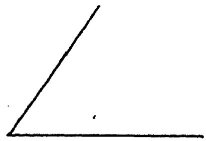


Fig. 4:20

2. Draw any triangle with a perimeter equal to the given line. (Sum of three sides equal to given line in length.)

Fig. 4:21

3. Divide this line into three equal parts.

Fig. 4:22

4. Draw a right triangle with the given line as its hypotenuse.

Fig. 4:23

5. Construct a line perpendicular to line AB at B. Use method shown on page 72. Fig. 4:19 (b).

A B

Fig. 4:24

6. Locate the center of this circle.

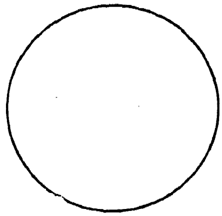


Fig. 4:25

7. Draw a line through the given point to the given line so that the angle formed will be equal to the given angle.

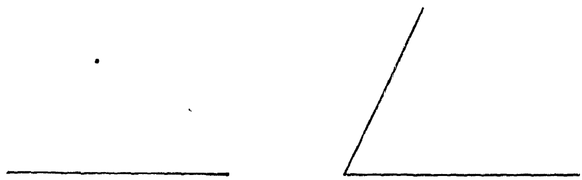


Fig. 4:26

8. Extend these two lines and connect them by an arc of 3/4 inch radius.

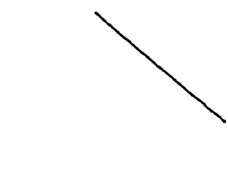


Fig. 4:27

9. Draw an arc of 7/8 inch radius so that it will be tangent to the given circle and the given straight line.

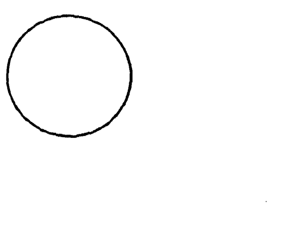


Fig. 4:28

10. Circumscribe a circle about the triangle given below.

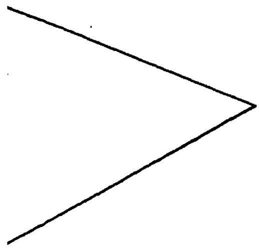
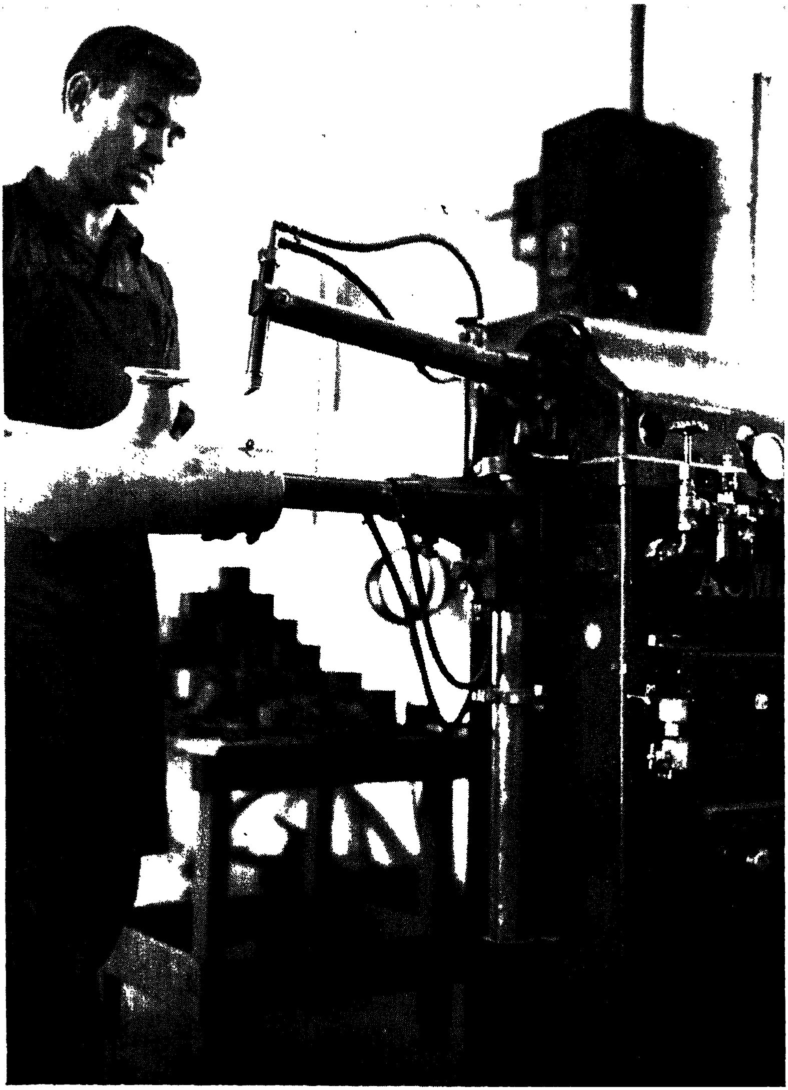


Fig. 4:29

11. Draw a circle 3 inches in diameter and divide the circumference into 6 equal parts with a compass.
12. The altitude of an isosceles triangle is $2\frac{1}{2}''$. Construct the triangle by the use of a compass.
13. Inscribe a hexagon in a circle which has a $1\frac{1}{2}''$ radius.
14. Inscribe a pentagon in a circle which has a 2″ radius.
15. Two lines intersect at a 45° angle. Draw an arc with a radius of $\frac{7}{8}''$ tangent to both lines.
16. Show two methods of drawing an ellipse. Make the major axis 4″ and the minor axis $2\frac{1}{2}''$.



Courtesy of Ryan Aeronautical Co.

Fig. 4:30—Welding stainless steel fittings to Ryan exhaust manifolds by spot welding process.

CHAPTER V.

ENGINEERING DRAFTING

5:1 Orthographic Projection.

The most common method of drawing a part is by orthographic projection. The method used in the United States, called the Third Angle Method, may be explained by visualizing a block in a glass box.

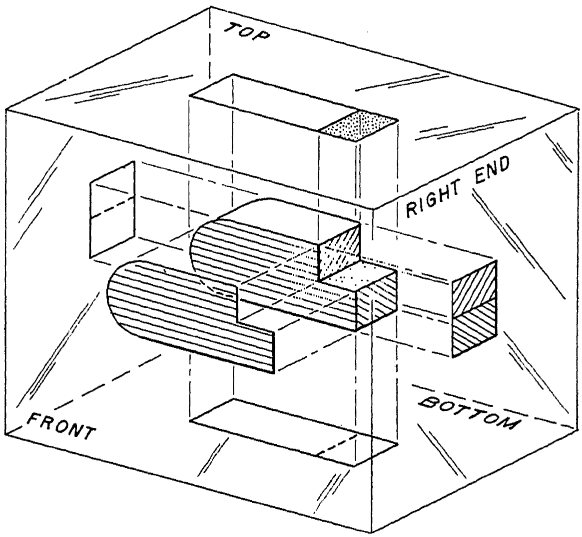


Fig. 5:1 Glass Box

If the views as seen through the various sides of the glass box were drawn on the respective sides, and the box unfolded as shown and laid out flat, we would have before us the Third Angle Method of Orthographic Projection, as standardized in the United States.

It is not always necessary to present all six views of an object. In the case of the block enclosed in the glass box, only the front and top views are necessary to describe the object. The front view, or principal view, as it is sometimes called, of an object is always the view that will give the most information concerning the form of the object. Such other views as are required to complete the information are then added.

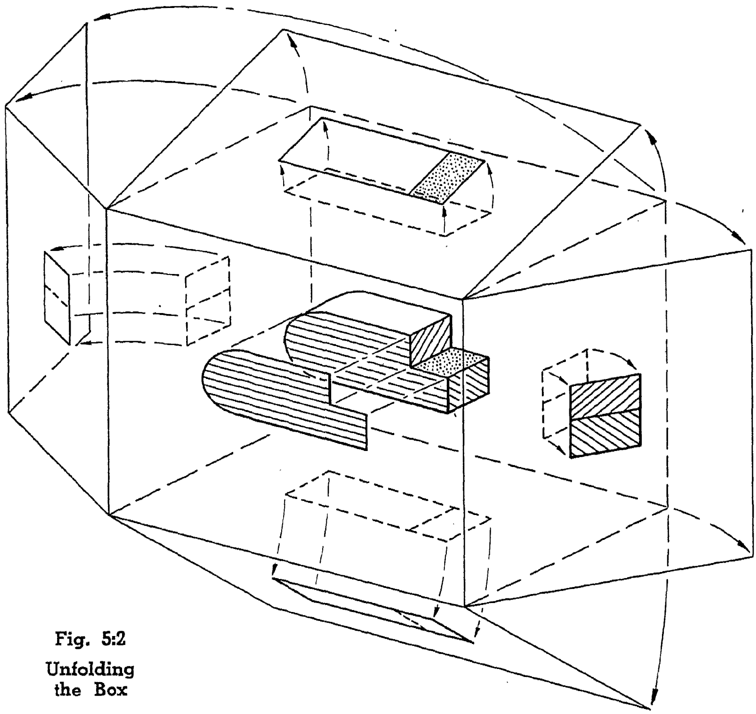


Fig. 5:2
Unfolding
the Box

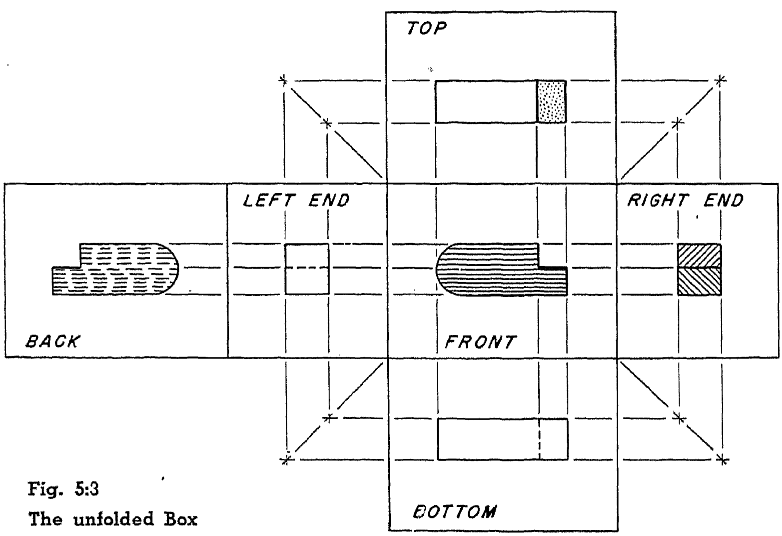
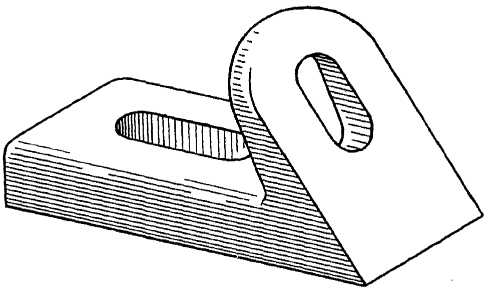


Fig. 5:3
The unfolded Box

5:2 Auxiliary Views.

An auxiliary view is used to project the face of an object that would not appear in its true length in a Third Angle Projection. The projection is usually made normal to the face or plane of the object, such as in the accompanying view.



Perspective View

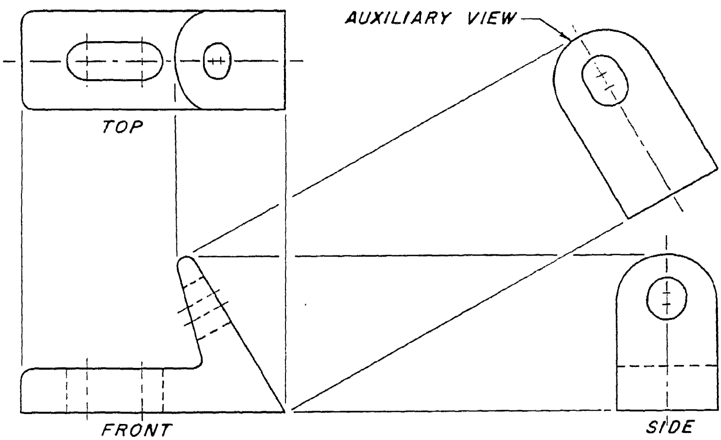


Fig. 5:4

Auxiliary views may be projected from any of the principal views at any angle other than 90°.

5:3 Isometric Projections.

One other method of pictorial drawing commonly used by Draftsmen in sketching to illustrate or use as a means of expression (See Freehand Sketching) is isometric projection. In isometric projection the part is drawn to the same scale as the orthographic projection. One edge is drawn in true length and

the square faces projected off at an angle of 30° with the horizontal. A block is shown below in isometric projection. Circles in isometric projection are elliptical in shape.

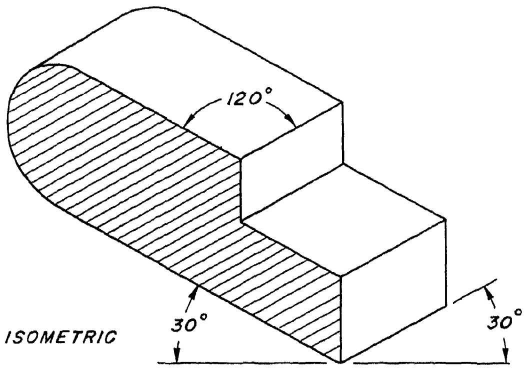


Fig. 5:5

5:4 Drawing Sheet Sizes.

American Standard drawing sheets sizes are given in Fig. 5:6. Sheet sizes A through F are multiples of the commercial letterhead, $8\frac{1}{2}'' \times 11''$. This permits the easy folding of tracings and blueprints so as to fit commercial standard letter files. Also, these sheet sizes may be cut without waste from 36 inch rolls of paper. Sheet sizes from G through T are rolled drawings and are used for large parts. Blueprints are always folded with the blue side out and in such a manner so as to have the title block on the outside where it can be read at all times.

5:5 Title Blocks.

In one corner (generally the lower right hand corner) of all blueprints will be noticed a rectangular block. This block is called a title block and is utilized as a record section of the Drawing, and as a source of information pertaining to the part or parts.

The title blocks as shown on the blueprints on the left hand pages of Chapter VIII are typical of those appearing on blueprints. These title blocks give various engineering information relative to the part, such as finish, heat treatment, weight, size, specifications, bill of materials, etc.

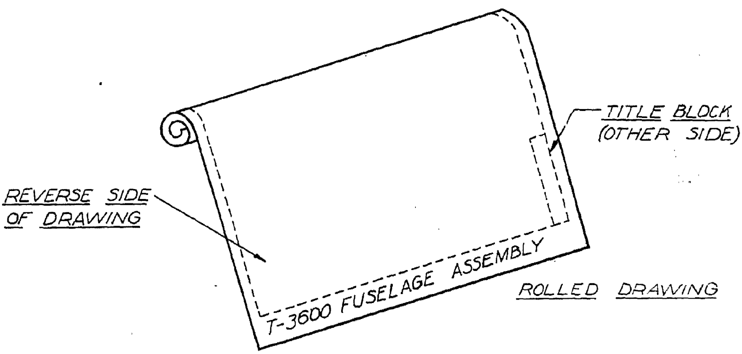
DRAWING SHEET SIZES

SIZE	A	B	C	D	E	F	G	H	I	J	K	L	M	N	P	Q	R	S
WIDTH	8.5	11	11	11	17	17	17	17	22	22	25.5	25.5	34	34	34	34	42	42
LENGTH	11	17	25.5	34	22	33	47	69	37	54	47	69	47	58	69	91	69	91

FLAT DRAWINGS (A–F) — ROLL DRAWINGS (G–S)

T
ANY STANDARD WIDTH BY ANY LENGTH OTHER THAN STANDARD

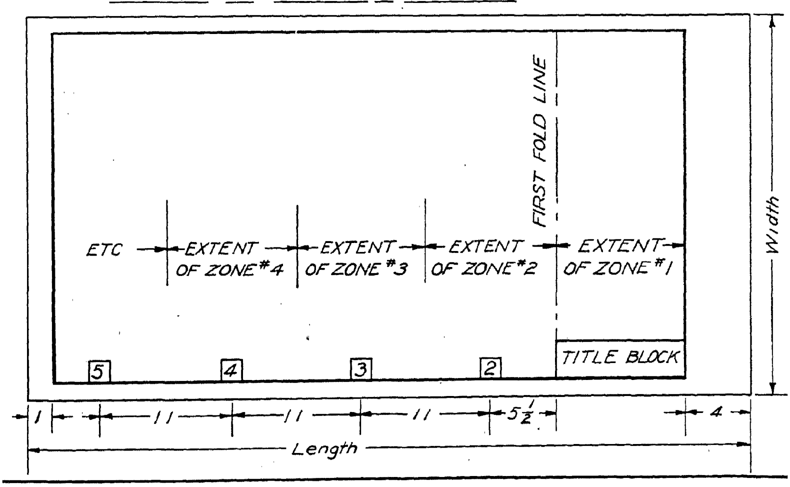
DRAWINGS B, C, D, E, AND F WILL FOLD TO SIZE A (8.5x11).



ROLLED DRAWING

ZONING

METHOD OF ZONING A DRAWING



5:6 Drafting Abbreviations.

Miscellaneous abbreviations used in drafting and general aircraft terminology:

— A —

Absolute Ceiling	A/C
Accessory	ACCES.
Actuating	ACT
Adjusting	ADJ.
Adjustment	ADJ.
After Bottom Center	A.B.C.
After Top Center	A.T.C.
Toward-Tail	AFT.
Aileron	AIL.
Air Corps	A.C.
Alclad	ALC.
Aluminum	ALUM.
Aluminum Alloy	AL. ALLOY
Ammunition	AMM.
Anneal	AN'L.
Antenna	ANT.
Approved Type Certificate	A.T.C.
Approximate	APPROX.
Army & Navy	A.N.
Arresting	ARREST.
Assembly	ASSEM.
Assistant	ASST.
Atmosphere	ATMO.
Attached	ATT.
Attachment	ATT.
Auxiliary	AUX.
Average	AV.

— B —

Baggage	BAG.
Battery	BAT.
Bearing	BRG.
Before Bottom Center	B.B.C.
Before Top Center	B.T.C.
Bill of Materials	B/M
Bottom Dead Center	B.D.C.
Bracket	BRKT.
Brake Horse Power	B.H.P.
Brake Mean Effective Pressure	B.M.E.P.
Brown & Sharpe Gauge	B.S.G.
Bulkhead	BLKD.
Bushing	BUSH.
Buttock Line	B.L.

— C —

Cancelled	CAN.
Carburetor	CARB.
Case Harden	C. HARD.
Casting	CSTG.
Cast Iron	C.I.
Center	CTR.
Center of Buoyancy	C.B.
Center to Center	C-C
Center of Gravity	C.G.
Center Line	C.L. ℄ or ℄
Center of Pressure	C.P.
Center Section	C.S.
Centigrade	C.
Centimeter	CM.
Chamfer	CHAM.
Change	CHNG.
Charge	CHG.
Check	CHK.
Chord Line	C.L.
Chrome-Molybdenum	C.M.
Circular Pitch	C.P.
Circumference	CIRCUM.
Clearance	CLEAR.
Cold Rolled Steel	C.R.S.
Commercial	COML.
Compartment	COMPT.
Compensating	COMPEN.
Complete	COMPL.
Compress	COMP.
Concentric	CONC.
Conduit	COND.
Connecting	CON.
Connection	CON.
Contract	CONT.
Control	CONT.
Corrugated	CORR.
Corrugation	CORR.
Counter Bore	C.B.
Counter Drill	C'DRILL or C.D.
Countersink	CSK.

Countersunk	CSK.
Coupling	COUPL.
Covered	COV.
Cubic	CU.
Cubic Feet	CU. FT.
Cylinder	CYL.

—D—

Degree	° or DEG.
Department	DEPT.
Design	DES.
Designation	DESIG.
Desired Loose Fit	DES. L.F.
Desired Tight Fit	DES. T.F.
Detail	DET.
Developed Length	D.L.
Developed Width	D.W.
Deviation	DEV.
Diagonal	DIAGN.
Diameter	DIA.
Diagram	DIAGR.
Differential	DIFF.
Dimension	DIM.
Dimension Chart	D.C.
Disconnect	DISCONT.
Disconnecting	DISCONT.
Distribution	DIST.
Distributor	DIST.
Ditto	DO
Dozen	DOZ.
Drafting	DFTG.
Draftsman	DFTSMN.
Drafting Room Manual	D.R.M.
Drawing	DWG.
Duralumin	DURAL

—E—

Each	EA.
Electrical	ELECT.
Electromotive Force	E.M.F.
Elevator	ELEV.
Emergency	EMER.
Enclosure	ENCL.
Engine	ENG.
Engineering	ENG.
Equipment	EQUIP.
Equivalent	EQUIV.
Estimate	EST.
Exhaust	EXH.
Experimental	EXP.
Extinguisher	EXT.
Extrusion	EXTR.

—F—

Fahrenheit	F.
Fairing	FAIR.
Federal	FED.
Feet or Foot	FT. or '
Figure	FIG.
Fillet	FIL.
Fillister Head	FIL. HD.
Fitting	FIT.
Flat Head	F.H.
Flexible	FLEX.
Flotation	FLOT.
Forward	FORWD.
Frequency	FREQ.
Front	FR.
Fuselage	FUS.

—G—

Gallons	GALS.
Galvanize	GALV.
Gage	GA.
General	GENL.
Generator	GEN.
Gram	GM.

—H—

Handbook	HNDBK.
Harden	HDN.
Hardware	HDWE.
Head	HD.
Headless	HDLESS
Heat Treat	H.T.
Heavier-Than-Air	H.T.A.
Hexagon	HEX.
Holder	HODR.
Hollow	HOL.
Horizontal	HOR.
Horse Power	H.P.
Hour	HR.
Hydraulic	HYD.

—I—

Ignition	IGN.
Inboard	INBD.

Inch .... IN.
Indicator .... IND.
Information .... INFO.
Inside Diameter........ I.D.
Inspection .... INSP.
Inspection Gage........ I.G.
Inspector of Naval Aircraft........ I.N.A.
Inspector of Army Aircraft........ I.A.A.
Installation .... INSTAL.
Instruction .... INST.
Instrument .... INST.
Instrument Panel........ INST. PANEL
Interchangeable .... INTER. CH.
Intermediate .... INTER.
Internal .... INT.

— J —

Junction .... JUNCT.

— K —

Key Way .... K'WAY
Knuckle Line........ K.L.

— L —

Landing .... LDG.
Landing Gear........ L.G. or LDG. GR.
Latitude .... LAT.
Leading Edge........ L.E.
Left Hand........ L.H.
Length .... LENG.
Longeron .... LONG.
Longitudinal .... LONG.
Lubricating .... LUB.
Lubrication .... LUB.

— M —

Machine .... MACH.
Main Beam .... M.B.
Maintenance .... MAIN.
Manufacturer .... MFR.
Material .... MATL.
Maximum .... MAX.
Maximum Loose Fit........ MAX. L.F.
Maximum Tight Fit........ MAX. T.F.
Mean Aerodynamic Chord........ M.A.C.
Mechanical .... MECH.
Mechanism .... MECH.
Meter .... M.
Miles Per Hour........ M.P.H. or mph.
Mill Cutter .... M.C.
Minimum .... MIN.
Minimum Loose Fit........ Min. L. F.
Minimum Tight Fit........ Min. T. F.
Miscellaneous .... MISC.
Mold Line .... M.L.
Mount .... MT.
Mounting .... MTG.

— N —

Nacelle .... NAC.
Naval Aircraft Factory........ N.A.F.
Number .... NO.
Number Required........ NO. REQ.

— O —

Observation .... OBS.
Observer .... OBS.
Obsolete .... OBS.
Opening .... OPNG.
Operating .... OPER.
Oscillator .... OSCIL.
Outboard .... OB.
Outside Diameter .... O.D.

— P —

Parachute Flare........ PARA. FLARE
Passenger .... PAS.
Patent .... PAT.
Pattern .... PATT.
Perforate .... PERF.
Permanent .... PERM.
Piece .... PC.
Pitch Diameter........ P. DIA.
Plate .... PL.
Position .... POS.
Pounds .... LBS.
Pounds Per Horse Power........ LBS/H.P.
Pounds Per Sq. Foot........ P.S.F.
Pounds Per Sq. Inch........ P.S.I.
Preliminary .... PRELIM.
Pressure .... PRES.
Production .... PROD.
Propeller .... PROP.

— R —

Radius .... R.
Receiver .... REC.

Receptacle .... RECEPT.
Reference .... REF.
Reinforcement .... REINF.
Reinforcing .... REINF.
Release .... REL.
Required .... REQ.
Requirements .... REQMTS.
Retainer .... RET.
Retaining .... RET.
Retracting .... RETRG.
Revised .... REV,
Revision .... REV.
Revolutions Per Minute .... R.P.M.
Right Hand .... R.H.
Round Head .... R.H.
Rubbing .... RUB.
Rudder .... RUD.

—S—

Sea Level .... S.L.
Section .... SECT.
Segment .... SEG.
Selector .... SEL.
Separate .... SEPT.
Service Ceiling .... S/C
Shear Beam .... S.B.
Shock Absorber .... SH. ABS.
Special .... SPEC.
Specification .... SPEC.
Specific Gravity .... SPEC. GRAV.
Spherical Radius .... SPH. R.
Square Feet .... SQ. FT.
Square Inch .... SQ. IN.
Stabilizer .... STAB.
Standard .... STD.
Station .... STA.
Steel .... STL.
Stiffener .... STIF.
Stock Length .... S.L.
Stock Width .... S.W.
Structure .... STRUC.
Supercharger .... SUPCHGR.
Superseded .... SUP.
Support .... SUP.
Supporting .... SUP.
Symmetrical .... SYM. or SYMM.
Synchronize .... SYNCHR.
System .... SYST. or SYM.

—T—

Temperature .... TEMP.
Thread .... THD.
Thrust Line .... T.L.
Trailing Edge .... T.E.
Transformer .... TRANSF.
Transmitter .... TRANSM.
Transverse .... TRANSV.
Typical .... TYP.

—U—

Ultimate .... ULT.
Universal .... UNIV.

—V—

Variation .... Var.
Vertical .... VERT.
Volts, Volume, Velocity V

—W—

Water Line .... W.L.

—Y—

Yards .... YDS.

—Z—

Zinc .... ZN.

5:7 Layout Drawing.

A layout is used to show clearly the shape or contour, size and location of some particular part or group of parts in the airplane in complete relation to other parts.

To fulfill this obligation, layouts must be of high standard workmanship or they will be of little value in determining detail design. Layouts pass through two stages of completion, (1) Preliminary

and (2) Final. No details are made until the final layout is approved.

For sake of clarity, a layout should show primarily the part or group of parts concerned. Views of other parts should be shown in **"phantom"** where necessary. Weight and quality of lines should be suitable for blueprinting; also for clear accurate reading, even when the layout is covered by a sheet of tracing cloth. 6H pencils are not recommended for layout work; a softer, well sharpened pencil being more desirable.

Layouts should not be converted into regular production drawings, but in their final stage should be suitable, both in workmanship and completeness, for blueprinting. Blueprints of layouts are used in connection with tool work (manufacturing jigs, dies, etc.). Also layouts must be complete enough that detailing can be done without reference to any other source of information. This is necessary because of the fact that, in many cases, detailing will be done by a specialized detail group.

5:8 Detail Drawing.

A detail drawing is a drawing of a single part, giving all dimensions and information needed to make the part. The design should be such as will permit making the part in a single fabrication department. Detail drawings do not go to assembly departments; therefore, notes such as "DRILL 1/8 on ASSEMBLY" are worthless on detail drawings and must appear on the assembly drawing where the operation is to be performed.

5:9 Assembly Drawing.

This drawing shows a group of parts fastened together to form a unit which may be installed as such in another assembly or in the plane itself. The assembly drawing should call only for previously fabricated parts, but may show dash numbers where the assembly will be made in one of the departments that does both fabricating and assembly work. However, if any of the parts of the assembly would have to be made in another department, then that part should be detailed separately on another drawing. The assembly drawing preferably has no **dash numbers.**

The assembly drawing will show the dimensions needed to locate the parts relative to each other, and in addition, if it has dash numbers, will show all dimensions needed to fabricate the details. It will call for A-N or other standard parts needed to assemble the

details, giving instructions for drilling, reaming, trimming, etc., where such information is pertinent.

All **sectional views** which are pertinent to a particular assembly should be shown on the same sheet with the assembly drawing itself.

5:10 Sub-Assembly or Sub-Installation.

It is desirable to have large assemblies broken down into a number of smaller sub-assemblies and sub-installations. This not only facilitates production, but permits the assembly drawing to remain clear of too many sectional views and avoids complication of the drawing by eliminating the **callout** of a large number of detail parts. Thus, on a fuselage structure assembly, the major drawing would call for very few parts, and a comparatively large number of sub-assemblies and sub-installations, such as "Installation—Window Frames," "Installation—Nose Baggage Door," "Installation—Cabin Door," "Installation—Main Bulkhead," "Installation—Nose Landing Gear Fitting," etc. The major assembly drawing in this case will show only sufficient dimensions to locate installations and sub-assemblies relative to one another, and will call for very few attaching parts. The bulk of all attaching parts should be indicated on the sub-installation drawings.

5:11 Final Assembly Drawing.

The final assembly drawing of any airplane is the index drawing for that particular model. There are no dimensions given, the drawing being devoted solely to the calling out of all major assemblies. In the case of some of the larger units, major assemblies are called out; then by means of brackets, all important sub-assemblies making up the unit are listed and labeled "REF." From these drawings, it is possible to locate all parts or related drawings.

5:12 Installation Drawing.

The installation drawing is for the use of one of the Assembly Departments, such as final assembly, and shows where and how one assembly is attached to another when such information is too elaborate to be given on the assembly drawing of the larger of the two assemblies in question. The installation calls for all attaching details such as angles, bolts, screws, etc.; it may call for the smaller of the mating assemblies; it must have no dash numbers. It generally shows only such few dimensions as may be needed to locate parts, or reference dimensions, which may be useful in subsequent engineering work.

5:13 Tool Design Drawing.

A special drawing made for constructing production tools, (dies, jigs, fixtures, machinery, etc.). It is generally made by a special department (Tool Design) independent of the engineering department.

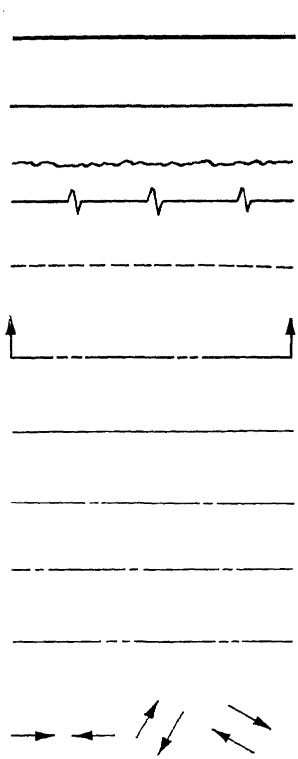
5:14 Checking

The purpose of checking is to insure that drawings are correctly made with regard to design, drawing, and "system." Each Draftsman is expected to check his own work carefully before it goes to a Checker, and is held responsible for its correctness. As an added precaution, Checkers are trained to find any additional errors on drawings before the drawings get to production departments. The mistakes a Checker finds are a direct reflection on the Draftsman. Those he misses are a reflection on the Checker. Errors discovered in the shop are a reflection on the engineering department. Close cooperation with the Checkers is an important factor and will insure each Draftsman that his drawing is going out correctly.

5:15 Lines and Line Work.

The types of lines and line widths as indicated are standard and should be used on all Engineering drawings and should be sufficiently dense to permit good reproduction. A sample drawing, showing the use of all types of lines, is illustrated in Fig. 5:10.

ALPHABET OF LINES



1. Extra Heavy: BORDER LINE
2. Heavy: VISIBLE OUTLINE
3. Heavy: BREAK LINE
4. Medium: INVISIBLE OUTLINE
5. Heavy: CUTTING PLANE
6. Thin: Extension (or Ray); DIMENSION: SECTION LINE
7. Thin: CENTERLINE
8. Thin: MOLD LINE Direction of Motion, etc.
9. Thin: PHANTOM LINE; Alternate Position: CONSTRUCTION LINE
10. Arrows—Slightly Concave sides; Length 3 to 4 times width

Line Dimensions

Extra Heavy Line	.025 in.	Long Dashes	$\frac{5}{8}$ to $\frac{3}{4}$ in.
Heavy Line	.015 in.	Medium Dashes	$\frac{1}{8}$ to 3-16 in.
Medium Line	.010 in.	Short Dashes	1-16 in.
Thin Line	.005 in.	Space between Dashes	1-16 in.
		Dots	1-64 in.

All Dimensions are Approximate—Not to be measured.

Fig. 5:7

5:16 Hidden Lines.

Hidden lines should be avoided as much as possible, sections being preferable in many cases. The standard use of hidden lines is as shown in Fig. 5:8.

All hidden lines, except for very small parts, should be at least $\frac{3}{16}$ of an inch to $\frac{1}{4}$ inch long. The length of hidden lines on small parts should be in proportion to the part.

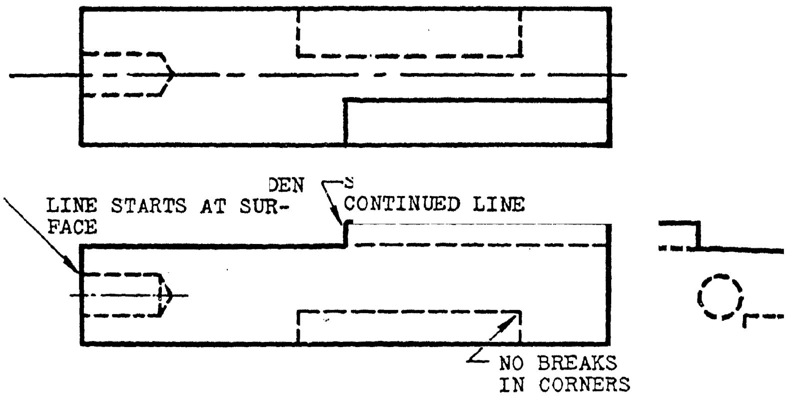


Fig. 5:8

5:17 Dimension and Extension Lines.

Dimension lines should be light lines, unbroken except for the space left for the dimension, and should be of the same weight as those indicated in Fig. 5:14.

Extension or ray lines should not touch the outline of the object by about $\frac{1}{16}$ inch, and should extend beyond the arrow heads by approximately $\frac{1}{8}$ inch, as shown in Fig. 5:16.

5:18 Break Lines.

Break lines on small parts are represented by heavy free-hand lines, as shown in Fig. 5:9. Break lines on assemblies or large parts are represented by light ruled lines and free-hand "zig-zags," as shown in Fig. 5:10.

Where it is necessary to show a long break which extends at least 3 inches and not over 12 inches, not more than 2 "zig-zags" should be shown. In breaks exceeding 12 inches, the "zig-zags" should be spaced not less than 4 inches apart.

The method of indicating the ends of shafts, rods, tubes, etc., which have a portion of the length broken out, is shown in Fig. 5:9. These breaks should all be made freehand.

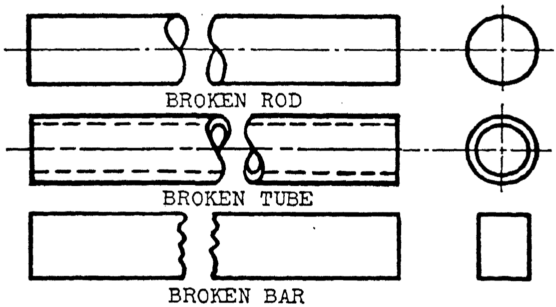


Fig. 5:9

5:19 Center Lines.

A center line is a fine broken line, made up of long and short dashes, alternately spaced. Note Fig. 5:7.

Standard conventions for showing center lines through parts may be noted in the various Figures given in this text.

5:20 Alternate Position Lines.

Alternate positions, or indication of the limiting positions of a moving part, should be shown by a phantom line. Fig. 5:10 shows very clearly a direct application of phantom lines as used for alternate positions.

5:21 Sectional Views.

Sectional views, or sections, should be used when the interior construction cannot be shown clearly by the outside views. The exposed cut surface of the material is indicated by "section lines" or "cross hatching," with uniformly spaced fine lines. The lines should be equally spaced, and the spacing should be from about $\frac{1}{16}$ inch on small drawings to $\frac{1}{8}$ inch on large drawings.

Hidden lines and details beyond the cutting plane should be omitted unless absolutely required to properly describe the object. Note Fig. 5:10. Sections must not be "rotated." When a section is removed from its normal projected position, it must maintain its proper orientation, i.e., with its reference plane parallel to the section cutting plane.

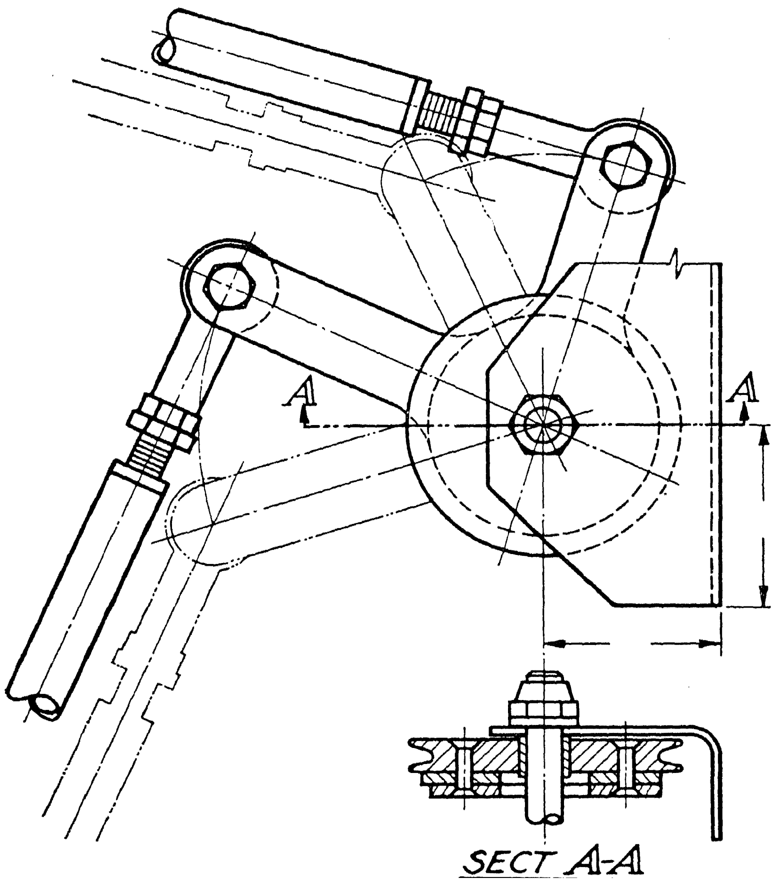


Fig. 5:10

5:22 Section Lining.

Section lining should be made with light parallel lines at an angle of 45° with the border line of the drawing. Two adjacent parts should be sectioned in opposite direction. A third, adjacent to both, should be sectioned at 30° or 60°. If cut in more than one place, the sectioning of any part should be the same in direction and spacing. If the shape or position of the part would bring

45° sectioning parallel to one of the sides, another angle should be chosen.

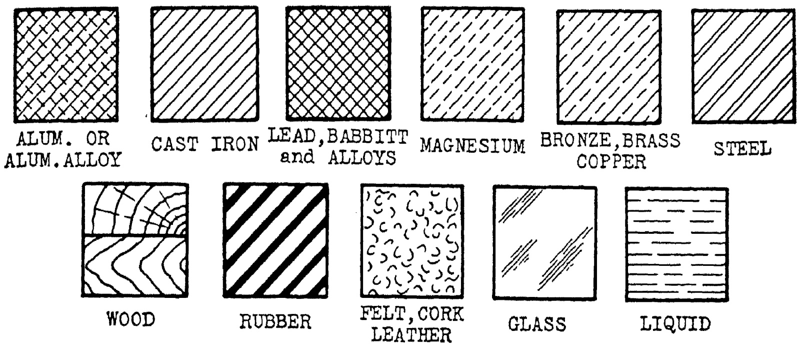


Fig. 5:11

Shafts, bolts, nuts, rivets, pins and similar parts, with axes in the cutting plane, should not be sectioned. Note Section A-A of Fig. 5:10.

Section plane through a thin web of a casting should be shown as in Fig. 5:12.

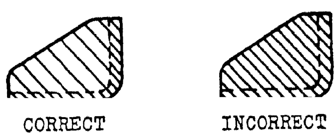


Fig. 5:12

Sectioning with colored pencils or crayons is permissible on layouts and experimental drawings. When crayon sectioning is used, all surfaces cut by the section plane should be filled in solid.

5:23 Alternate Sectional Views.

Cross sections of materials .125 or thinner on detail or assembly drawings may be filled in solid, but lightly, with pencil.

5:25 Shading.

Shading of outline to indicate depth of part, or shading of contours, bends, cylinders, etc., is not standard practice in orthographic reproductions and should be avoided.

Shading is permissible only on very complicated layouts where it may help to distinguish intricate parts.

5:26 Dimensioning.

Do not dimension parts to explain how they were drawn but to show how they will be made.

All drawings must be so dimensioned that the parts shown thereon can be made exactly as intended by the Designer-Draftsman without the necessity of scaling the drawing or recourse to other information than that given.

The dimensions should include those sizes and distances which will be worked to in actual Shop operations, and should be so given that computations in the Shop will not be necessary. No dimensions should be given other than those actually required to produce the part. There should be no duplication of dimensions.

Dimensions from visible lines rather than from hidden lines, as shown in Fig. 5:13, should be given.

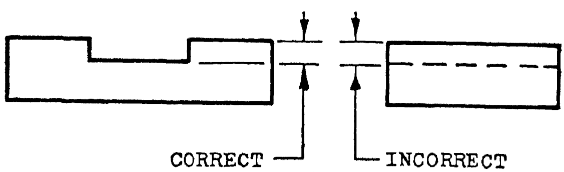


Fig. 5:13

5:27 Dimensioned Figures.

All dimensions should be given in **inches.** Inch marks (″) are not used. All dimensions should be placed to read from the lower edge of the drawing (to the right and bottom wherever possible). Wherever possible place all dimensions outside of views.

Dimensions in decimals should be carried to at least three places. Decimal points should be made heavy.

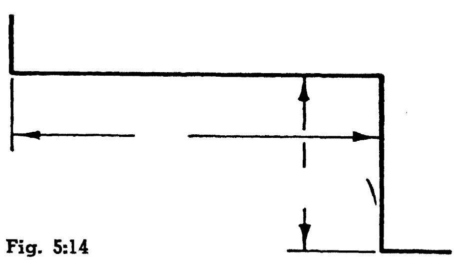


Fig. 5:14

5:28 Dimension Lines.

Two dimension lines should not cross each other. If this condition should exist, one line should be broken as shown in Figs. 5:14 and 5:15.

The dimension line will not be broken when dimensioning a part that is shown broken.

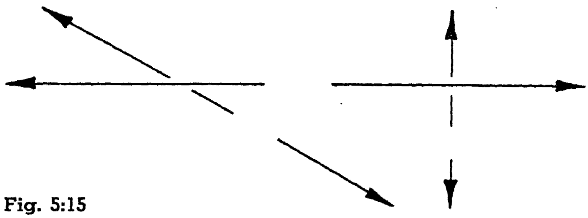


Fig. 5:15

5:29 Arrow Heads.

Arrow heads should be three or four times as long as they are wide. Their size should be in proportion to that of the drawing. See Fig. 5:15, article 5:17.

5:30 Crowded Dimensions.

When a number of dimensions of increased lengths are located on either side of a center line, etc., the figures should be staggered as in Fig. 5:16b, rather than in line.

5:31 Consecutive Dimensions.

Consecutive dimensions should be arranged in a continuous line, as in Fig. 5:16a.

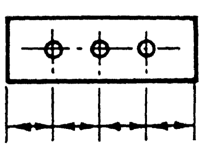


Fig. 5:16a

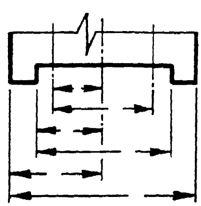


Fig. 5:16b

5:32 Over-all Dimensions.

Over-all dimensions should always be given and be placed outside the intermediate dimensions. Fig. 5:17.

Progressive dimensions should not be used on any type of drawing because it is very easy to introduce **cumulative errors.**

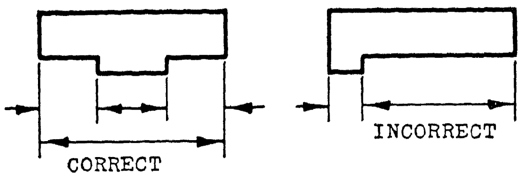


Fig. 5:17

5:33 Dimension on Cross-Hatch

When a dimension must be placed on a cross-hatched surface, leave an area free from hatching in which the dimension is placed, as shown in Fig. 5:18.

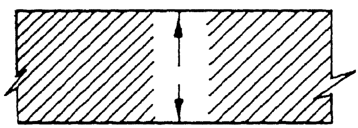


Fig. 5:18

5:34 Dimensioning Circles and Radii.

A dimension indicating the diameter of a circle should be followed by the abbreviation "DIA" except where it is obvious from the drawing that the dimension is a diameter.

The dimension of a radius should always be followed by the abbreviation "R." The center should be indicated by a cross, and the dimension line should have one arrow head. See Fig. 5:19.

When the center of an arc is located off the sheet, the radius should be given as shown in Fig. 5:20.

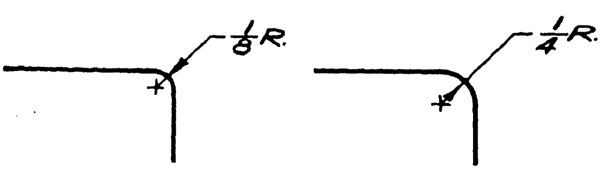


Fig. 5:19

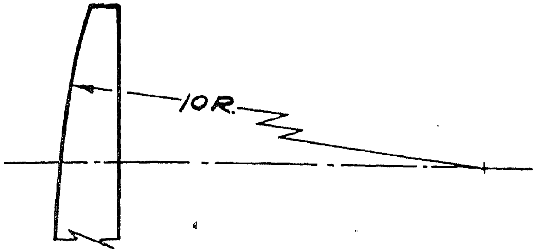


Fig. 5:20

5:35 Dimensioning Sheet Metal Parts.

All the pre-mentioned rules for dimensioning are generally applicable to sheet metal parts. The exceptions and specific dimension requirements for sheet metal parts are covered thoroughly in the following articles:

32nds have been accepted as the smallest fractional dimension on sheet metal parts; 64ths should be avoided unless absolutely necessary for items such as contours.

All dimensions must be to the same side of the metal, as in Fig. 5:21.

Dimensions on sheet metal parts are generally given to the mold lines, as shown in Fig. 5:21.

All sheet metal angles should be dimensioned by showing the outside angle. See Fig. 5:22.

All contour offsets should be spaced three inches apart wherever possible. However, if this spacing is not adequate, smaller spacing is permissible.

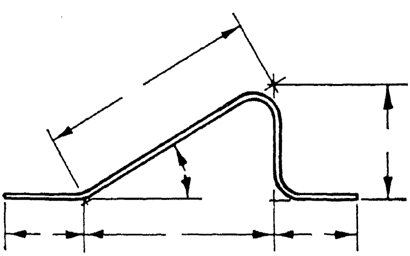


Fig. 5:21

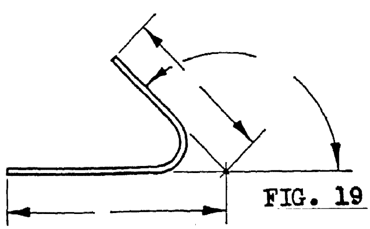


Fig. 5:22

All joggles should be dimensioned from the original mold line of the part. The length of the joggle should be indicated by dimensioning the flat surface. See Fig. 5:23.

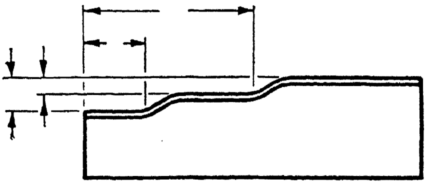


Fig. 5:23

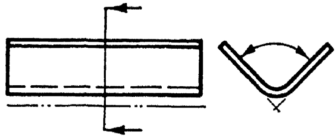


Fig. 5:24

Where the true angle is not already shown in the plane of the paper, a **section** should be taken perpendicular to the mold line. Fig. 5:24.

Dimensions which are taken in the plane of the metal (other than angles) should be clearly marked "IN THE PLANE OF METAL," or "TRUE."

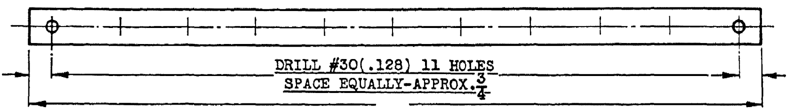


Fig. 5:25

When a part requires several holes to be drilled in a series, and all are equally spaced, the holes should be dimensioned as shown in Fig. 5:25. When it is necessary to locate holes, rivets, cutouts, etc., on assembly drawings, the dimensions should be tied in with some measurable point on the largest piece in the assembly.

5:36 Dimensioning Machined Parts.

General dimensioning practice is also applicable to machined part drawings. All machined parts must be completely dimensioned without cross-reference to any other part, this being a step toward interchangeability of parts.

5:37 Dimensioning with Tolerances.

Dimensions which must be held to close tolerances, should be dimensioned in decimals to at least three places, and the drawings should give the limits between which the actual measurements must come.

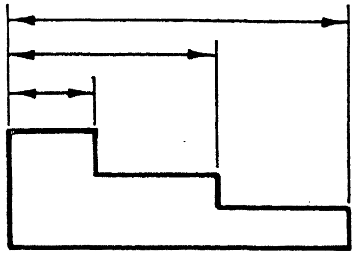


Fig. 5:26

5:38 Base Line Dimensioning.

When extreme accuracy is required, dimensions from a base surface may be used to avoid **cumulative errors,** and to reduce chance for error when changes are made. See Fig. 5:26.

5:39 Lettering.

Lettering is the most important part of working drawings. Dimensions, specifications, bill of material, and such other necessary information come under the head of lettering. Costly mistakes, sloppy looking drawings, wasted time and material can be avoided by the development of careful, neat lettering habits.

The single stroke Gothic letters, inclined or vertical, are universally used by draftsmen. By single stroke, it is not meant that the letter is executed in one single continuous movement of the pencil, but it is formed by one or more stems and curves, each of which is made with a single stroke.

Inclined capital letters are generally preferred and used in all cases because it comes more natural to the average person, and is therefore, faster and neater. Dimensions, notes, etc., should be $\frac{1}{8}$" high. Title letters should be $\frac{3}{16}$ inches high. Section letters should be $\frac{1}{4}$ inch high. Numerals for tolerance notes should be $\frac{3}{32}$ inches high. Space between lines of lettering should be $\frac{1}{8}$ inch. Lightly drawn ruled guide lines are often used in lettering. In many cases the use of various types of mechanical lettering guides is permitted.

5:40 Freehand Sketching.

Sketching is the basis of Mechanical Drawing. A person with a knowledge of mechanical drawing can find sketching a quick and valuable means of expression. Time can be saved and mis-

ABCDEFGHIJKLMNO

ABCDEFGHIJKLMNOPQRSTUVWXYZ &

0123456789

ABCDEFGHIJKLMNOPQRSTUVWXYZ &

0123456789

Fig. 5:27

takes avoided in laying out of templates if a rough freehand sketch is made first.

All that is needed for freehand sketching is pencil, paper and eraser. A soft pencil, such as an H or HB, should be used. The paper can be anything with good erasing qualities; although, for those whose sense of proportion is not so good, cross-section paper serves as a guide for straight lines and an approximate scale.

The same rules of projection are followed in sketching as were used in mechanical drawing. Orthographic, oblique, isometric, or perspective projections may be used.

5:41 Sketching Technique.

Straight lines should always be drawn as a series of short segments, later connected. This enables you to keep your line rather straight. Horizontal lines should be drawn with the pencil perpendicular to the line and tilted at about 45° to the paper. Vertical lines should be drawn by quick downward movement of the fingers.

Circles and arcs may be more easily drawn by boxing. This consists of drawing a square or octagon for sketching a circle or a rectangle for an ellipse.

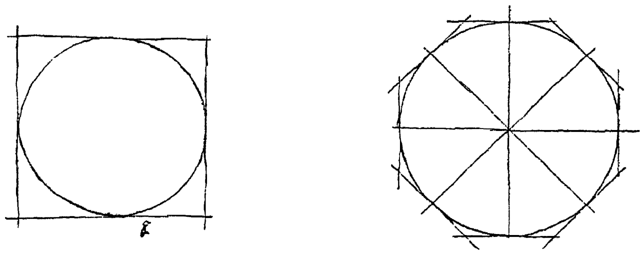


Fig. 5:28

5:42 Order of Drawing Construction.

There is a definite prescribed order of constructing a drawing. First of all, the draftsman should make a free-hand sketch of the object to be drawn. When he is ready to start the mechanical drawing, the following order of operations should be followed:

(1) Draw center lines (4H pencil).
(2) Block in views with construction lines.
(3) Draw circles and important areas.
(4) Draw fillets and rounds.
(5) Draw and/or darken horizontal object lines. (H or 2H pencil)
(6) Draw and/or darken vertical object lines.
(7) Draw and/or darken inclined object lines.
(8) Draw section lines.
(9) Draw extension lines and dimension lines (3H or 4H pencil)
(10) Add arrowheads, dimension, and notes (H or 2H pencil)

5:43 True Dimensions.

Many times reference is made to true lengths of lines, sizes of angles, etc. In all cases it refers to the exact or full size measurement of the line or angle. Oftentimes the line or angle does not lie in the plane of the paper. Under these conditions its true length

is not readily ascertained and some means must be found to determine its true length, in order that it can be used in a design or layout of a flat pattern.

5:44 True Length of Lines.

In some cases it may be necessary to find the actual or true length of lines or surfaces, i.e., the length of lines and surfaces that do not lie in a plane normal to the line of vision of the observer. Stating this in another manner, we can say the observer must look at the line or surface from a right angle and, in this case, all points on the line or surface are equidistant from the observer, before he can see or measure the true length.

When it becomes necessary to find the true length of a line and graphical methods are used, special attention must be given to the accuracy desired. Paper shrinkage caused by changes in humidity and inaccuracies due to improper drawing surfaces or tools and their uses are factors to be considered. With proper care, however, the graphical method can be correct within the customary tolerances desired. In cases where extreme accuracy is required (especially in large drawings), the drawings are sometimes made on metal or wood as in lofting. In some cases of small structures, where exceptionally accurate measurements of true lengths are necessary, mathematical calculations are used.

5:45 Determining True Lengths.

A complete discussion of the methods of determining true lengths of lines properly belongs to a text on descriptive geometry. It varies in accordance with the problem at hand. As far as the template maker is concerned we need only concern ourselves with the true length of straight lines in a few applications and using a simple case of applied algebra, trigonometry and descriptive geometry.

For a simple case of finding the true length of a line, inclined to both the vertical and horizontal, let us consider the case of a pyramid as shown in Fig. 5:29.

The oblique line T-B running from top to bottom does not show its true length in either the front or the top view. Since the base is flat and horizontal, the top view shows the true length of the distance from O, the center of the base, to the corner B. The vertical height (h) can be obtained from the front view. A vertical line T-O from top to bottom will make a right angle with the base, so a right triangle TOB can be constructed using true length of

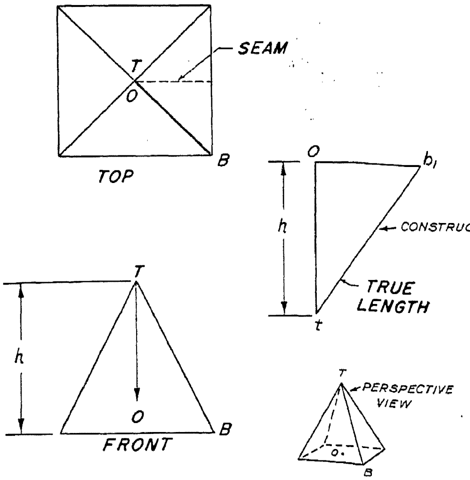


Fig. 5:29

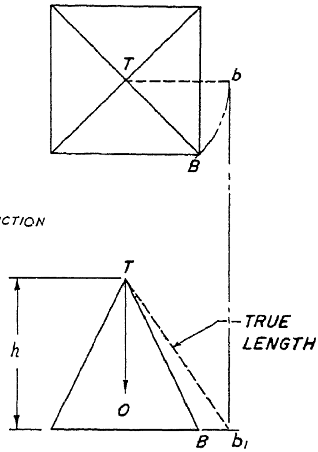


Fig. 5:30

OB from the top view as one leg and true length (h) from the front view as the other. The true length of TB will then be the hypotenuse of this triangle.

The true length of line TB can also be obtained by rotating it around point T in the top view (See Fig. 5:30), until it is parallel to the base. The length of this line in the top view is then projected down to the base line (extended) in the front view). A line from T to b_1 gives the true length of line TB.

The true length of line TB can also be found by two mathematical methods which will be illustrated. (1) The top view shows the true length of the base line OB (Fig. 5:29) and the front view shows (h), the true length of the line TO. We know that the two lines form a right triangle; from algebra we know that the hypotenuse of a right triangle is equal to $\sqrt{h^2 + (OB)^2}$.

Also from trigonometry, $\frac{OB}{TO}$ = Tangent of angle OTB

and $\frac{OB}{\text{sine angle } \overline{OTB}}$ = TB. Ref. Chapter III.

Fig. 5:31 is practically identical to Fig. 5:29 excepting that the apex of the pyramid is not directly over the center of the base. Each of the true lengths of line, OB, OB_1, OB_2, AND OB_3 must be found separately.

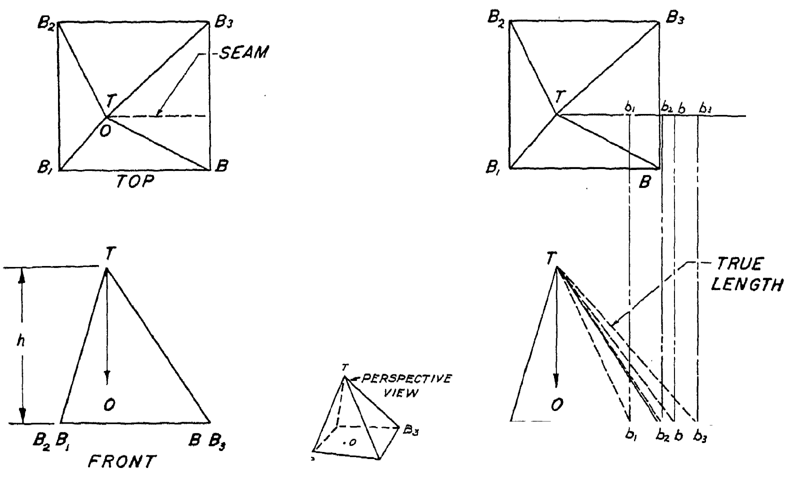


Fig. 5:31

Fig. 5:32 is similar to Fig. 5:29 and 5:30 except that the base lines are not horizontal and the true length of OB must be found in addition to that of TB. To find the true length of these use the same methods as used in Fig. 5:29 and 5:30.

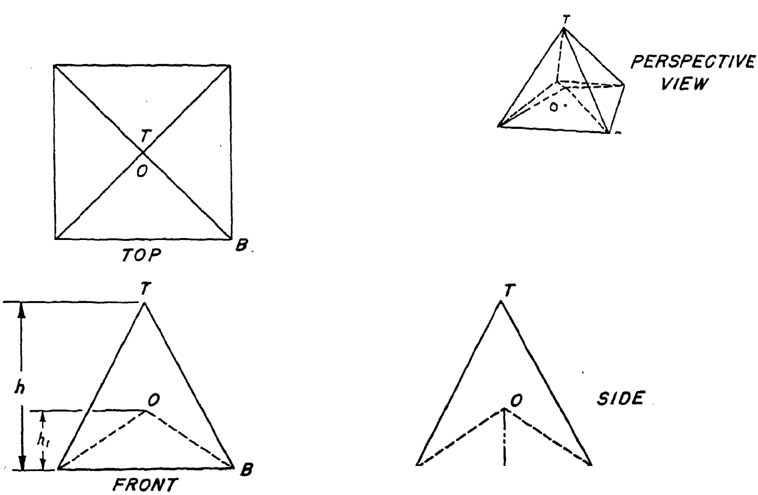


Fig. 5:32

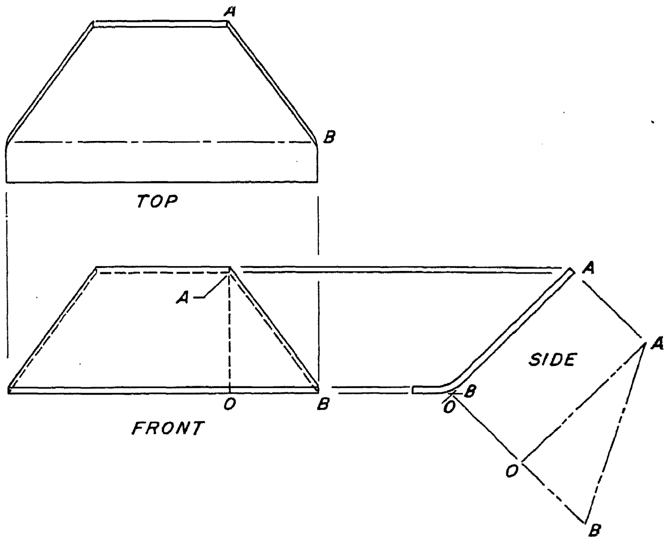


Fig. 5:33

Fig. 5:33 is a typical angle part. The edge AB is not shown in its true length in any view given in this figure. This is in keeping with the customary drafting practice, since the experienced person has no difficulty in calculating the true length.

If a perpendicular is drawn from point A in the front view to the outside mold line, it will intersect the mold line at point O. This line would lie in the plane of the metal and would appear in its true length in the side view.

The front view gives the true length on the mold line that point O is from B. From this information we can construct a right triangle using the true length of OA as one leg and the true length OB as the other leg. The hypotenuse of this triangle would be the true length of line AB. The hypotenuse AB can be measured from the constructed triangle or it may be calculated by the Pythagorean theorem; e.g.,

$$(AB)^2 = (OA)^2 + (OB)^2$$

and $$AB = \sqrt{(OA)^2 + (OB)^2}$$

To calculate the true length of the diagonal AB of the box shown, first analyze the situation. Try to find a right triangle that has AB as one of its sides. It can be seen if the point B is connected to the

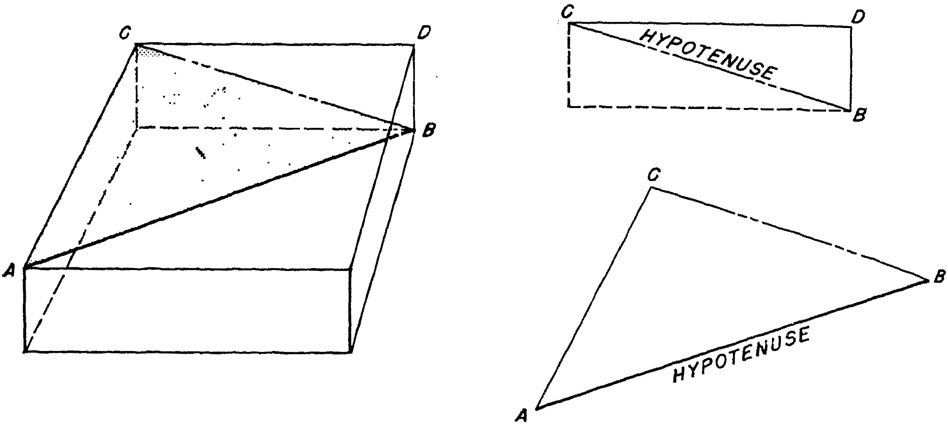


Fig. 5:34

opposite point C, the right triangle ACB is formed. AC is known, (the length of the box). CB is not immediately apparent, but is found from right triangle BDC with known sides BD and CD. The steps followed in the solution are as follows:

$$(CB)^2 = (CD)^2 + (BD)^2 \quad (1)$$

and $$(AB)^2 = (CB)^2 + (AC)^2 \quad (2)$$

substituting in (2) value of $(CD)^2 + (BD)^2$ for $(CB)^2$ in order to use the given dimensions AC, CD and DB.

$$(AB)^2 = (CD)^2 + (BD)^2 + (AC)^2$$

and $$AB = \sqrt{(AC)^2 + (BD)^2 + (CD)^2}$$

CHAPTER VI

PRINCIPLES OF MATHEMATICAL DEVELOPMENT

6:1 Bend Allowance.

In the process of forming sheet metal parts, it is evident that stretch, shrink and other deformations within the metal itself will be unavoidable. This may be more easily understood by examining the following sketch.

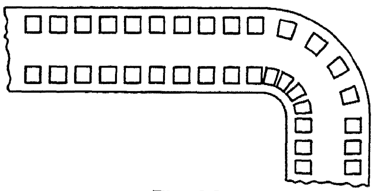


Fig. 6:1

Imagine the small squares as molecules of the metal. Note how these molecules are squeezed closer together at the inside of the bend and stretched apart at the outside of the bend. Only by trial and error can one tell exactly how much or how little metal shrinks on forming, as various metals behave differently. The deformation depends on how the metal is formed. Metal bent on a brake may stretch more than the same metal which is bent in a different manner, steel may shrink less than aluminum, etc. Nevertheless, a formula has been devised from hundreds of trials under all conditions. Averages of all of these trials have been found to be accurate within the limits of which the workmen can accurately measure and work.

The predetermined amount of metal which is required and included in the area between the beginning and ending of the bend is known as th **Bend Allowance,** sometimes referred to as B.A. It is the amount of metal (distance) required, in the flat stock, to allow for the bend.

The formula so devised to give this value is known as the **Empirical Bend Allowance Formula:**

$$(.01743\ R + .0078\ T)\ \propto^{\circ} = B.A.$$

In this formula, R is the inside Radius as shown in Fig. 6:2. T is the thickness of the metal, $\propto^{\circ}$ is the number of degrees in the bend as noted on Fig. 6:2. B.A. is the Bend Allowance.

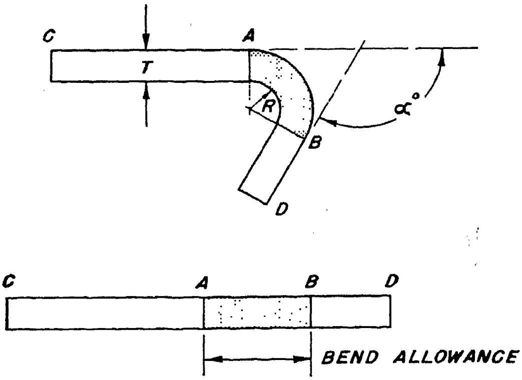


Fig. 6:2

The number of degrees in a bend is always given as the number of degrees through which the metal is bent, angle $\alpha°$ as shown in above figure.

Bend Allowance Charts:

In order to simplify the calculation of bend allowances, charts have been assembled giving the B.A. for various metal thicknesses and bend radii for one degree bends. See appendix. The value obtained from the chart when multiplied by the number of degrees in the bend will give the B.A. There is also a chart giving the complete B.A. for 90° bends, see appendix. It is advisable for the student to thoroughly understand the use of the empirical formula before relying completely on the bend allowance charts.

The use of the Bend Allowance Chart is self-explanatory.

Problems:

1. Find the bend allowance for a 90° bend in .032 thick material and a 1/8 Bend radius. Use Empirical Formula.
   Using bend allowance charts in the Appendix:
2. Find the bend alowance for a 117° bend in .040 material. Bend radius = 5/32.
3. Find from the chart, the alowance for a 3/16 radius bend in a piece of .064 23ST **alclad.** Bend to be 90°.
4. What is the bend allowance for a 37½° bend of 1/16 radius Material: X4130 Steel, .050 thick.

5. A piece of (.020) 24SO alclad is bent around a 1/4 radius through 60°. How much metal should be allowed for the bend?

6. Calculate the **developed width** of the flat for this section.

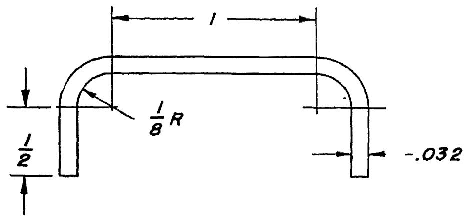


Fig. 6:3

6:2 Mold Lines.

As seen in problem 6 of the preceding section, flat developments can be made with use of the bend allowance, if the **flange** dimensions, etc., are given from the point at which the bend begins. However, this is not always the case. Dimensions are usually given to what is called the **mold line.** Basically, a mold line is the line formed by the intersection of two planes or surfaces. In this case it refers to two imaginary lines extended to the point of intersection from two non-parallel surfaces. See Fig. 6:4.

As dimensions are usually given to this mold line, we will learn how to calculate the developed length when this is the case. First, we will take up the simple case of a 90° bend. In the following figure, the data for the general case is shown:

Upon closer examination, it will be seen that in this particular case, the value of the dimension F, from the edge of the part to the beginning of the bend, can be calculated by subtracting the sum of T + R from D. This is apparent from the following figure:

Obtaining the value of D — (T + R), which we shall designate by the letter F, we have simply to add to this the value of the B.A. and the second F value of the section, and we have the developed width. Let us illustrate these findings with a numerical case.

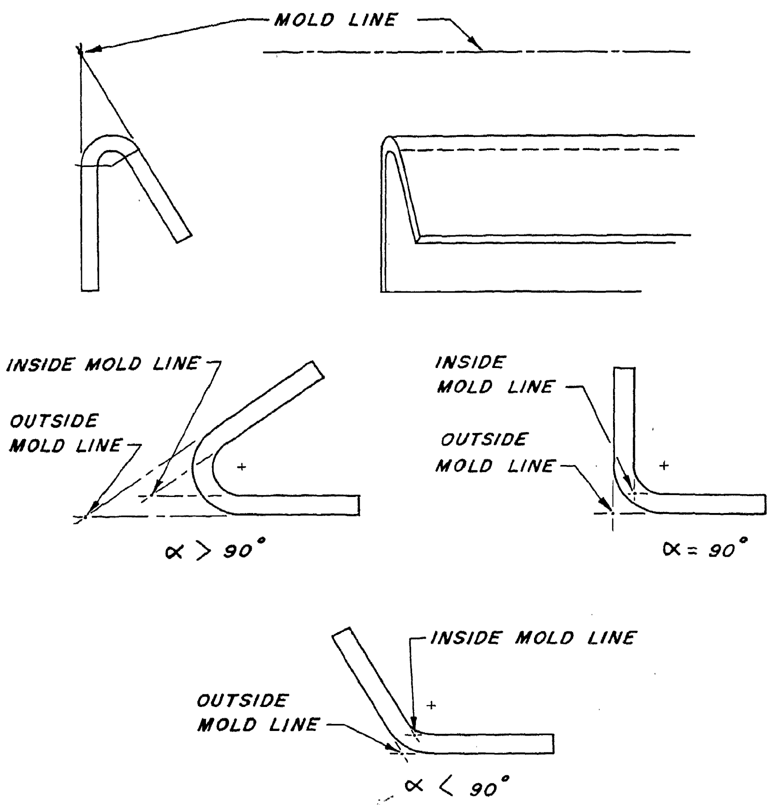


Fig. 6:4

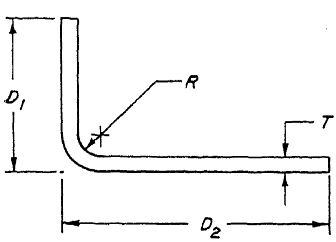


Fig. 6:5

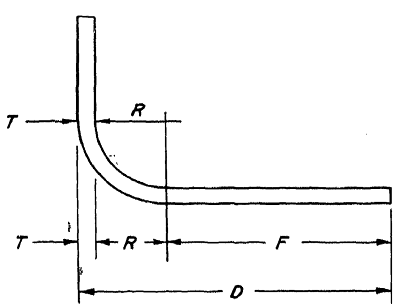


Fig. 6:6

Example: Find the developed width of the section shown.

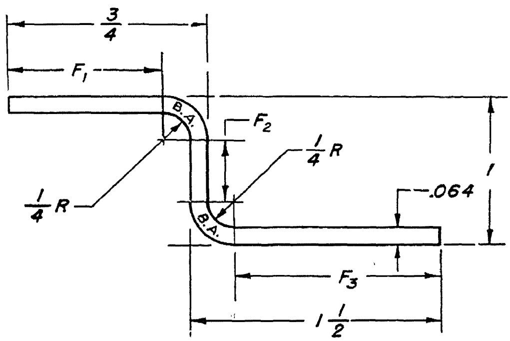


Fig. 6:7

Solution: One might choose either end of the section as a starting point. Suppose we start at the left end. The first value we wish to find is designated in the figure as F_1. Notice that F_1 is 3/4 minus the sum of thickness plus radius:

$$F_1 = .750 - .064 - .25 = .436$$

Next find the $(B.A.)_1$ for this bend. This value is found to be .4374. The distance F_2 is seen to be 1 minus twice the sum of thickness plus radius:

$$F_2 = 1.000 - .128 - .500 = .372$$

The second bend allowance $(B.A.)_2$ is the same as the first. F_3 is $1\frac{1}{2}$ minus the sum of thickness plus radius.

$$F_3 = 1.500 - .064 - .25 = 1.186$$

Adding up all of these values, we have the developed width:

.436	F_1
.4374	B.A.
.372	F_2
.4374	B.A.
1.186	F_3
2.869	D.W.

Problems.

1. Find the developed width of a right angle section with both

flanges 1 inch (mold line to edge of metal). The thickness is .040, and the bend radius is $\frac{1}{8}$.

2. Find the developed width of the section given in Fig. 6:8. All bends are 90°.

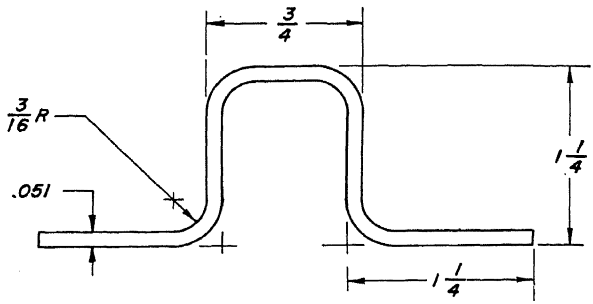


Fig. 6:8

6:3 Developed Widths, other than 90°.

A more complex problem confronts us in calculating the developed width of sections with bends other than 90°. Let us ex-

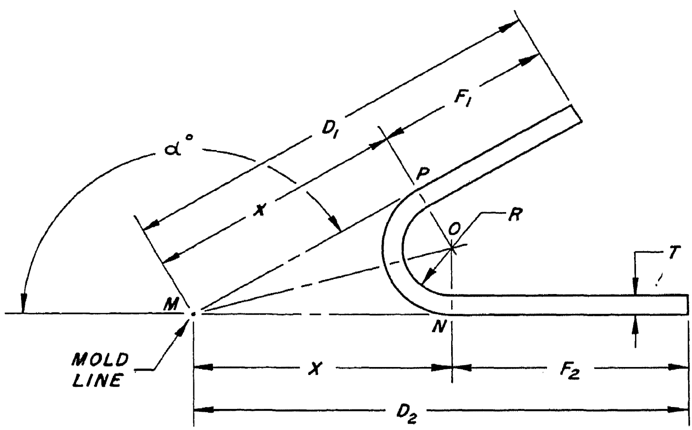


Fig. 6:9

amine two general cases. First with the **bent up angle** more than 90°, and second case with the bent up angle less than 90°.

Case 1. $\alpha > 90°$.

On studying Fig. 6:9 it is apparent that the developed width can be easily found when values are obtained for F_1 and F_2. This value can be found by subtracting X from D_1 and D_2 respectively. To evaluate X, consider the angle PON.[6] This angle can be proved to be equal to the given angle α. If O, the center of the radius, is connected with M, the mold line point, the line MO will bisect the angle PON. This gives the angle MON the value $\frac{1}{2}\alpha°$. Now consider the triangle MNO with right angle at N. Taking the angle MON as the operating angle we have:

$$\tan \measuredangle \text{MON}^7 = \tan \alpha = \frac{\text{Side opposite}}{\text{Side adjacent}} = \frac{\text{MN}}{\text{NO}} = \frac{\text{X}}{\text{T-R}}$$

Solving for X

$$\text{X} = (\text{T} + \text{R}) \tan \frac{\alpha}{2}$$

This is the formula that is always used to determine the X-distance for bends greater than 90° and, as will be shown later, it is also valid for bends of less than 90°.

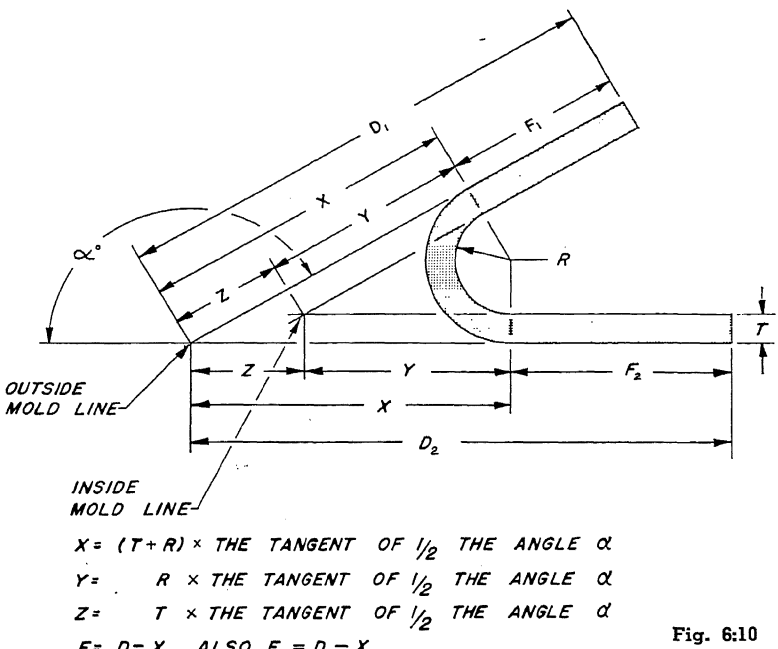


Fig. 6:10

[6] When labeling angles by letters, the middle letter is understood to locate the vertex of the angle. The other letters designate the leg of the angle.

[7] The symbol $\measuredangle$ is used to designate the word "angle."

If the bend is exactly 90°, we have seen that value of the X-distance was taken as simply T + R. To verify this value and show that it is in accord with the above formula the case for 90° will be evaluated.

$$X = (T + R)\tan\frac{\alpha}{2} = (T + R)\tan\frac{90^\circ}{2} \quad (T + R)\tan 45^\circ$$

$$X = (T + R)\tan 45^\circ$$

$$\tan 45^\circ = 1.00000$$

$$\therefore X = T + R$$

It is evident from symmetry that the value for X will be the same on each leg of the angle, therefore the developed width is seen to be:

$$\text{developed width} = D_1 + D_2 - 2X + \text{B.A.} \quad (\text{for } \alpha^\circ)$$

Case 2. $\alpha < 90°$.

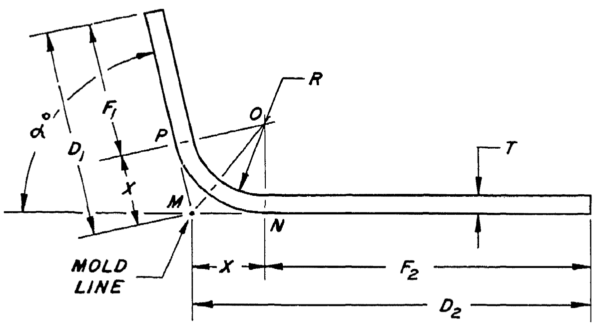


Fig. 6:11

As in case 1, the angle PON equals α, and angle MON equals α Therefore we have:

$$\tan \measuredangle MON = \tan\frac{\alpha}{2} = \frac{MN}{NO} = \frac{X}{(T + R)}$$

$$X = (T + R)\tan\frac{\alpha}{2}$$

This is the same as the formula derived for Case I, so we conclude that the X-distance for any bend equals the tangent of half the bent up angle times the sum of the thickness plus the radius.

To illustrate the use of these formulas, let us find the developed width of the section shown on Fig. 6:12.

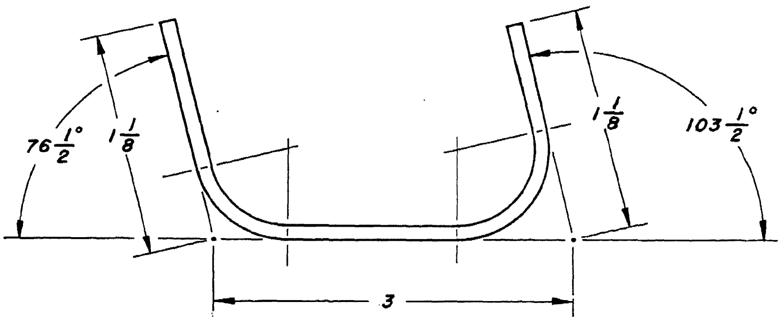


Fig. 6:12

Example: Find the developed width of the section shown: Metal thickness being .025 and bend radius $\frac{3}{32}$.

Beginning at the end of the $76\frac{1}{2}°$ flange and proceeding to the right, we have as the value of the first flat distance:

$$F_1 = D_1 - X_1 = 1.1250 - (.0250 + .09375) \tan 38\frac{1}{4}°$$
$$F_1 = 1.1250 - (.11875)\ (.78834) = 1.0314$$

The B.A. for one degree, $\frac{3}{32}$ radius bend of .025 material is found from the B.A. Chart to be .00183:

$$B.A._1 = 76.5 \times .00183 = .1400$$

The second or mid-flat section is:

$$F_2 = D_2 - X_1 - X_2 = 3.0000 - X_1 - (.11875 \tan 51\frac{3}{4}°)$$
$$F_2 = 3.0000 - .09362 - (.11875)\ \ (1.2685) = 2.7557$$

The second B.A. is:

$$(B.A.)_2 = 103.5 \times .00183 = .1894$$

The last flat section is:

$$F_3 = D_3 - X_2 = 1.1250 - X_2$$
$$F_3 = 1.1250 - .15063 = .9744$$

Therefore, adding up all of these values we obtain for the developed width:

F_1	1.0314
$(BA)_1$	.1400
F_2	2.7557
$(BA)_2$	.1894
F_3	.9744
Developed Width	5.0909

Problems.

1. Calculate the developed width for the section shown: Metal thickness is .051 and bend radius is $\frac{3}{16}$.

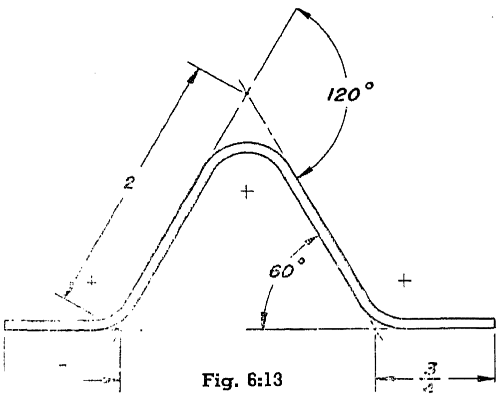


Fig. 6:13

2. Draw the outline of the flat pattern of the part shown. Mark in the value of the developed width.

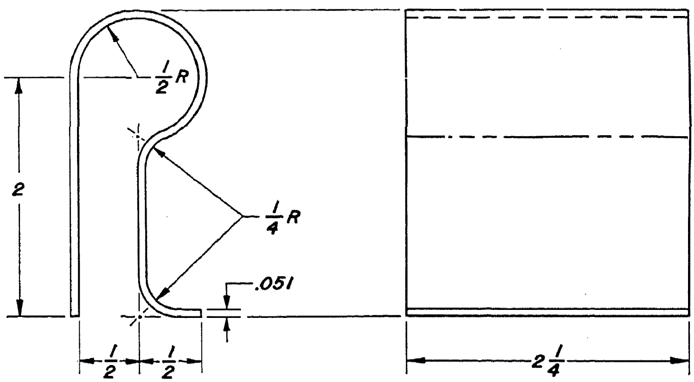


Fig. 6:14

6:4 Block Lines and Inside Mold Lines.

It is common engineering practice to give all dimensions for an individual part to the same side of the metal. That is, dimensions will be given to the mold lines formed by the intersections of the various surfaces of the part that would form one and the same surface in the flat pattern. This practice serves to eliminate many errors due to blemishes on the blueprint, etc. In certain

cases the use of a new concept is required to be able to fulfill these conditions. That is the use of inside mold lines.

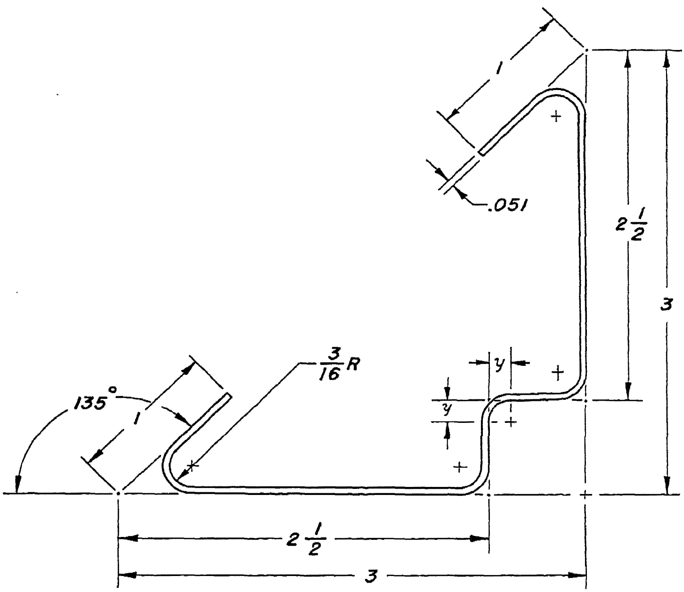


Fig. 6:15

The dimensioning of points to the inside mold lines is shunned as much as possible unless a case, such as mentioned above, necessitates their use.[8]

A case where the use of inside mold lines would be considered practical is shown in Fig. 6:15.

Using figure 6:15 as an example, the developed width can be found by the method explained in article 6:3, with the exception of the value of both of the dimensions indicated as the Y-distance. It is evident from the figure that in this case, Y equals the radius of the bend.

From reasoning analogous to that of article 6:3 for determining the value of the X-distance, it can be shown that for bends other than 90°:

$$\text{Y distance} = \text{R} \times \tan \frac{\alpha}{2}$$

See Fig. Nos. 6:9, 6:10 and 6:11

We are now equipped to obtain the developed width of any section.

[8] For this reason, dimensions on parts with only 90° bends often jump from one side of the metal to the other in order to always dimension to the outside mold line.

6:5 Theory of Development.

In order to obtain a clear understanding of what is meant and expected by the term development, imagine the unfolding of a box. See Fig. 6:16. Note that as each side is folded down, it maintains a fixed position relative to its bottom edge. The side may be said to be rotating about this edge as an axis. Note that the four axes of rotation (of the four sides) remain fixed with the bottom of the box. The final pattern may be said to be developed in the plane of the bottom panel.

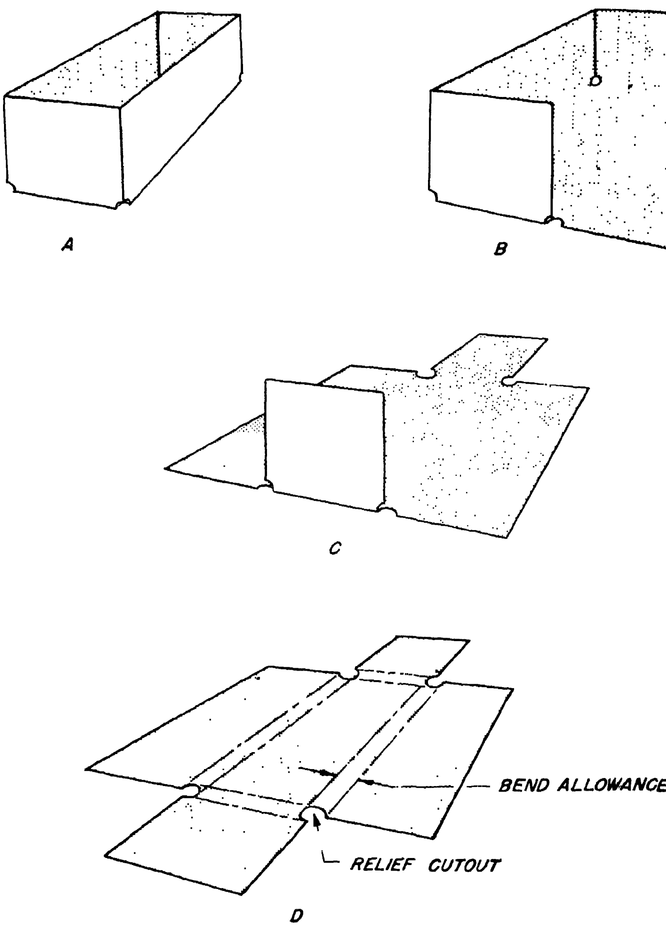


Fig. 6:16

Suppose the box had a cover made from the same piece of material. See Fig. 6:17. Here is seems that the axis of rotation of the cover is not fixed; however, if the sides are first rotated into the plane of the base and the cover then folded down, it is seen that the axis of rotation of the cover remains fixed.

It is general practice when developing a flat pattern to choose one face of the object as a reference plane and work out from this face to complete the development.

In actual aircraft work square corners are not used. The metal must be formed around a radius to prevent it from cracking. It is for this reason that Bend Allowance, X-distances, Set-Backs, etc., are brought into the developments.

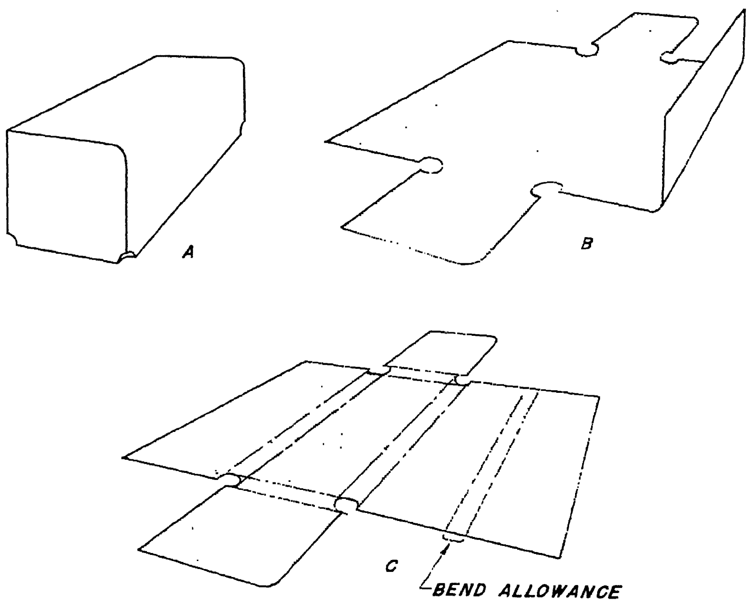


Fig. 6:17

Now reconsider a similar box, with a definite thickness and formed around a definite radius. See Fig. 6:18. In this box, the logical choice of reference plane would be that of the base face, labeled face A in the figure. Drawing in the given mold lines of this face Fig 6:19 is obtained.

When convenient, all of the remaining lines should be measured from two of these mold lines.

First, establish the bend lines at which face A just begins to bend. As the bends are all 90°, come back from the mold lines a

distance equal to the thickness of the metal plus the radius. In this case, these dimensions are:

$$.0625 + .1875 = .25 \qquad \text{See Fig. 6:20.}$$

Continuing outward, measure the bend allowance from the above bend lines to obtain lines for the end of each bend. The B.A. is found from the chart. The thickness .0625 is not found on the chart, but we can use the value for .063 which is the nearest thickness to .0625 given. The B.A. in this case is .3384. See Fig. 6:21.

The distance .088 from the base mold line to the second bend line was obtained by subtracting the X-distance (.250) from the B.A. As will be learned in article 6:6, the mold line is not in the

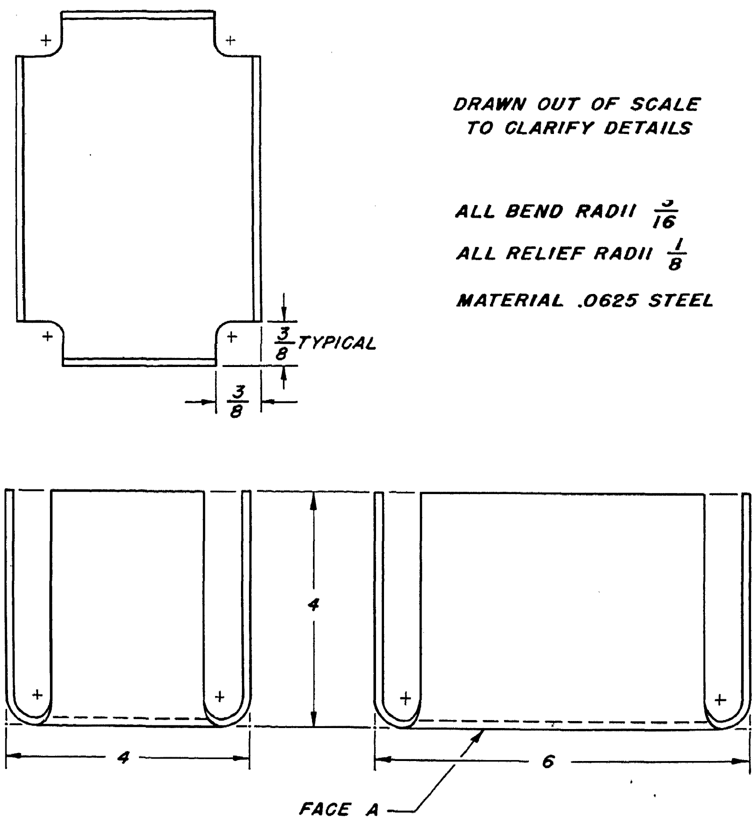


Fig. 6:18

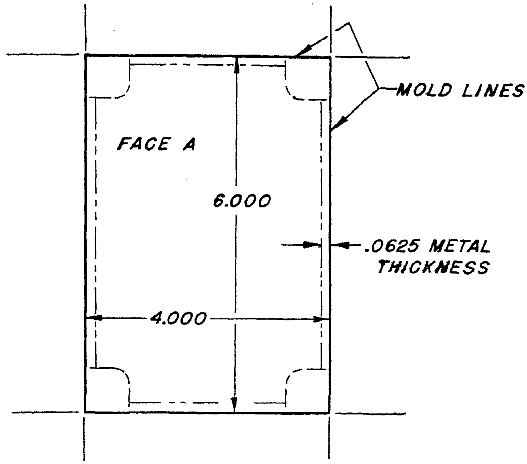


Fig. 6:19

center of the bend allowance. This mold line developed from a side instead of the base would be .088 from the other bend line. At this point, the extreme outer boundary of the pattern can be drawn. This outer edge is known to be 3.750 from the outer bend line (found by subtracting the X-distance which is .250 from the overall dimension which is 4.000). In actual layout, dimensions would be added and subtracted in order to be able to measure

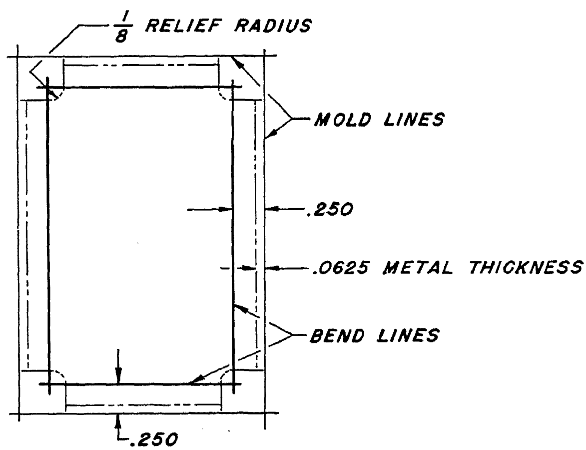


Fig. 6:20

this dimension from the mold line. When this line is established Fig. 6:22 can be drawn.

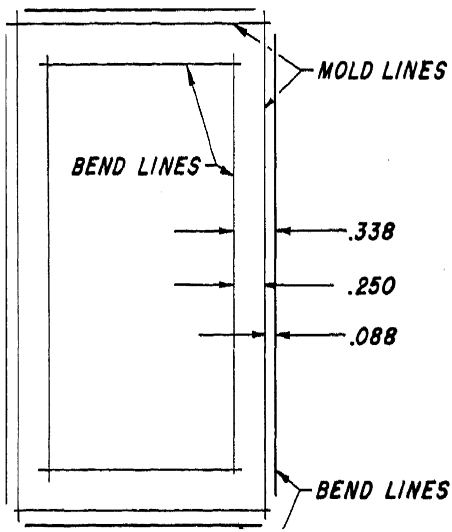


Fig. 6:21

Now, there only remain the corner cutouts to be made. On re-examining the figure notice that the dimensions controlling the width of the flanges is the 3/8 dimension taken in from the mold line. This dimension happens to be the same for all sides of this part. (This is not always the case, however.) Measuring in this amount from the original mold lines the edges of the four sides can be drawn.

The figure calls for 1/8 relief radii, and to complete the layout, it is necessary to relieve the inside corners of the cutout with 1/8 radii. It is inferred from the original figure that these relief radii are to be drawn tangent to the cutout sides. Therefore, completing the layout, our pattern will look like the following when cut out:

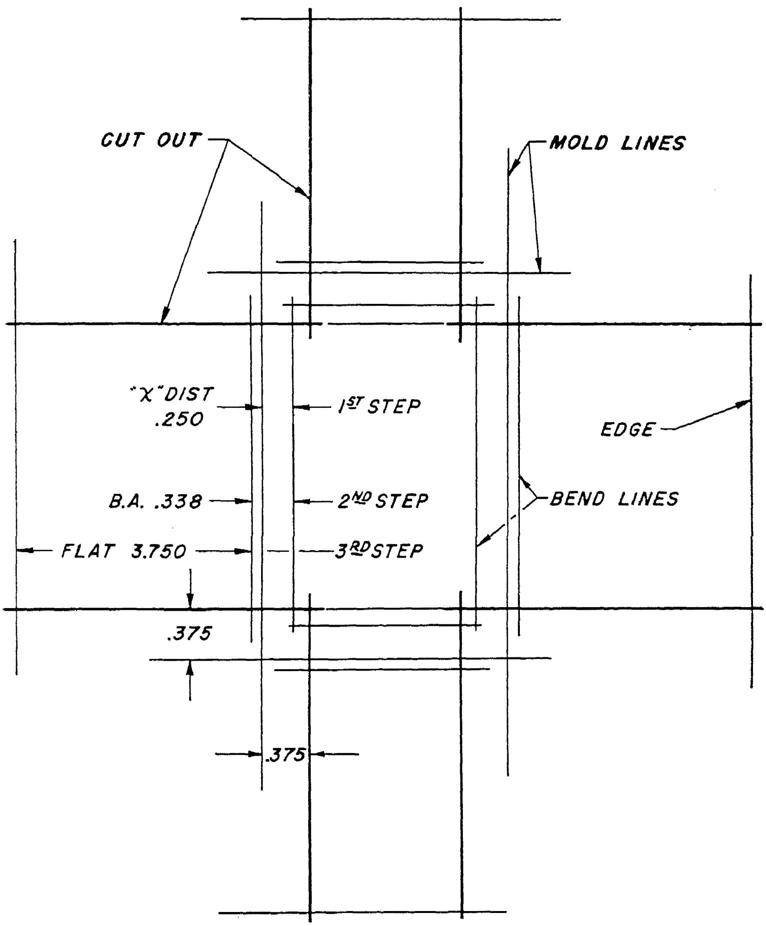


Fig. 6:22

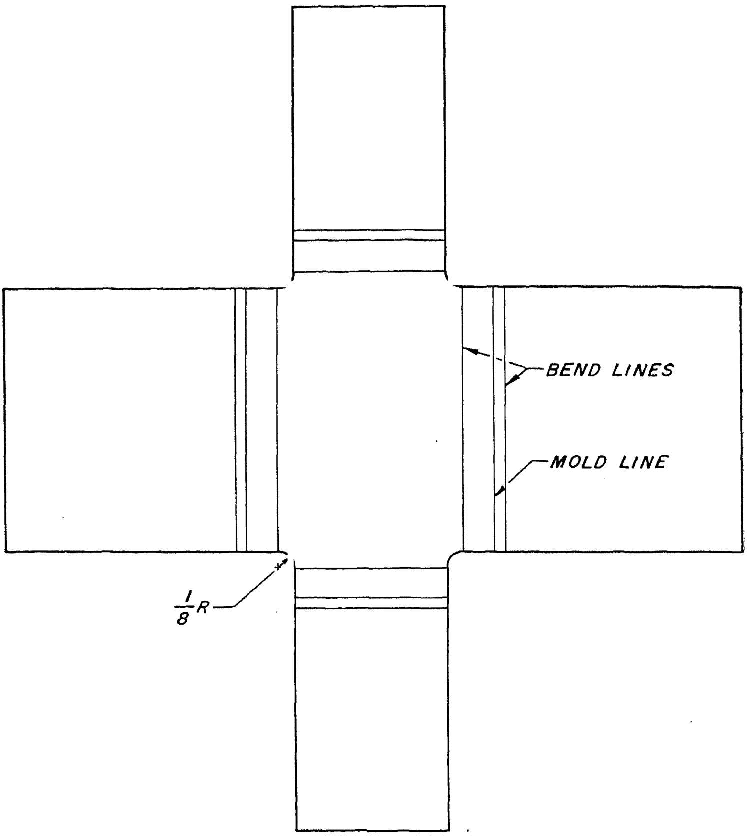


Fig. 6:23

6:6 Transforming Mold Lines into Flat Pattern.

It is of interest to note what happens to the mold line when the bend is opened into the flat. Figuratively speaking, the mold line seems to divide into two lines when the bend unfolds. This fact will be more apparent in the following figure:

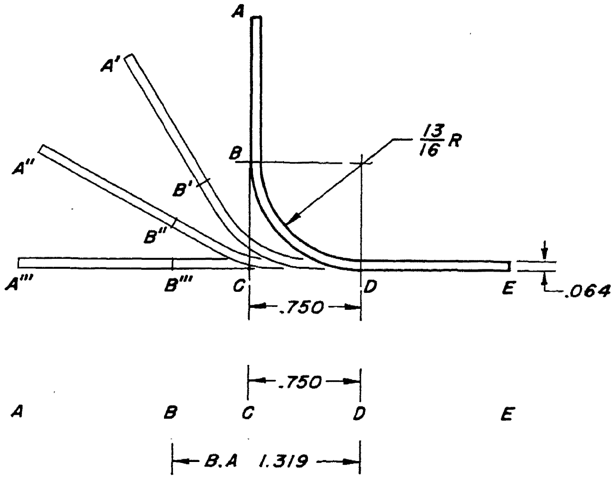


Fig. 6:24

Note how, although the distance CD remains constant, the distance BC shortens to B‴ C.

We know that the bend may be considered to open from either side. We will think of it opening opposite to the above case:

Note that in this case, BC remains constant and CD diminishes to CD‴.

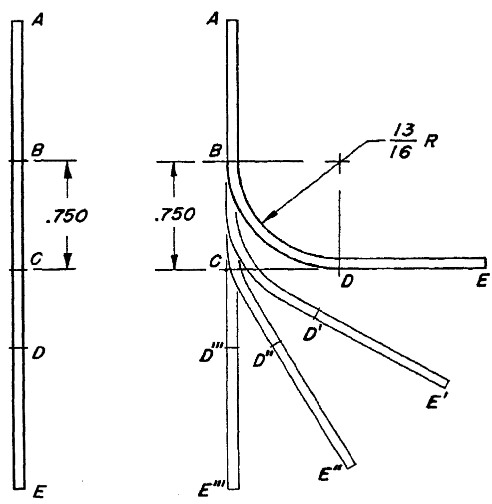


Fig. 6:25

Combining the two cases, we have Fig. 6:26.

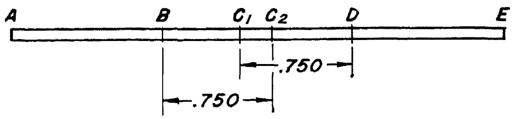


Fig. 6:26

The concept of two mold lines forming from one when a part is developed should be thoroughly understood as it is one of the most common sources of error in template layout. The points C_1 and C_2 may be either within the two bend lines or outside of the bend lines, but in any case, the distance BC_1 will equal DC_2 and $BC_2 = DC_1 = X$ distance.

6:7 Set Back.

Some manufacturers use the Set Back method of determining allowance for bends. This consists of finding the distance (on the flat pattern) between the two outside mold lines of each bend. In Fig. 6:26, C_1 and C_2 are the two outside mold lines of the bend and the distance between them is the set back. This distance is calculated from a special Set Back Chart. See appendix.

The developed length of the part shown in Fig. 6:24 and Fig. 6:25 would be (AC + EC) — set back, or as shown in Fig. 6:26, $(AC_2 + EC_1) - C_1C_2$.

6:8 Diagonal Cut Development.

Frequently parts are fabricated requiring diagonal cuts across the part, therefore the student should familiarize himself with the method used in determining the outline of the cuts in the flat pattern. See Fig. 6:28.

It must first be determined which view of the part is to be used as the basis of the template layout. This would be the view which gives the major outline and dimension detail, the view from which the balance of the part can be most readily developed. In the case of Fig. 6:28 this would be the front view.

The next step required is to layout a developed blank which is the width of the part in the front view and is the developed length for the part. Now draw all bend lines completely across the blank located in their correct relationship to it, also draw mold line "A",

Fig. 6:27—Spinning Circular Parts Over a Form Block

"X" distance from bend line No. 2, and mold line "B", "X" distance from bend line No. 3. (In the front view of Fig. 6:28 the bend lines No. 2 and No. 3 are drawn in to show their relationship to mold lines "A" and "B". It is readily seen that in this view mold lines "A" and "B" are "X" distance from bend lines No. 2 and No. 3 respectively.

In the development blank locate point "E" on mold line "A", point "F" on mold line "B" and points "D" and "E" on the top and bottom lines of the blank. Draw straight lines connecting "D" to "E", "E" to "F" and "F" to "G", thus completing the outline of the diagonal cut in the flat pattern.

If it is desired to hold the diagonal cuts as seen in the bottom view of Fig. 6:28 we would get a slightly different outline in the flat pattern than the one we have just obtained from the front view development.

A line has been drawn in the bottom view of Fig. 6:28 showing the position of bend lines No. 4 and No. 1 in the formed part. It is readily seen that this line is "X" distance from mold lines "A" and "B". Therefore in the development blank we locate mold lines "A" and "B", "X" distance from bend lines No. 4 and No. 1 respectively. Now locate points "D", "E", 'F" and "G" on their proper lines in the development blank. Connect all points with straight lines, thus completing the flat pattern.

From the above it is seen that we have two different templates for the same part—depending on the view from which we develop the pattern. In cases of this kind it must be determined which view is desired to be held, or is the most important. By using this view for our development we will hold the diagonal cut where it is most important and have only a slight deviation in the other view.

In cases of this kind it is sometimes desirable to neglect the mold lines and run the outline of the diagonal cut to the center of the bend allowance.

6:9 Spring-Back.

When metals having elastic properties are bent through a certain angle so that the material is stressed beyond its yield point, the material, after the pressure has been relieved, has a permanent set which is less than the angle through which it was bent. The

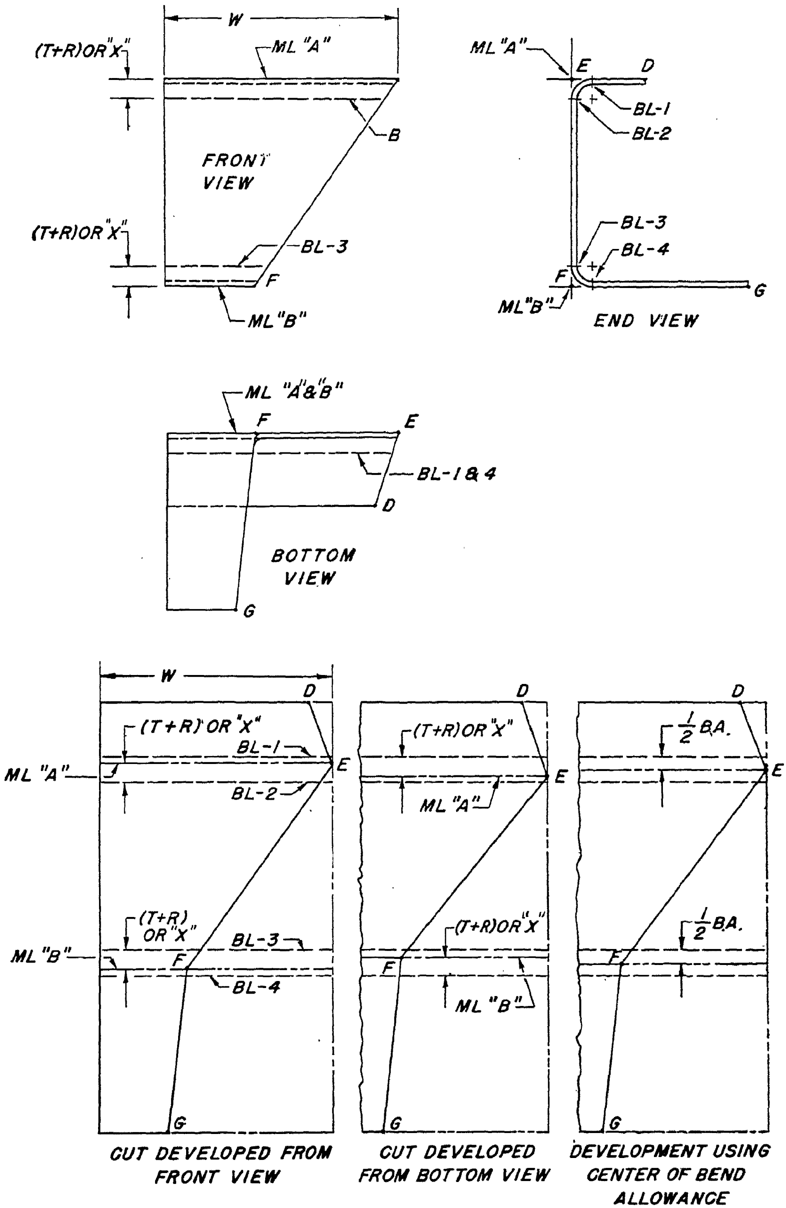

W
(T+R) OR "X"
ML "A"
B
FRONT VIEW
(T+R) OR "X"
BL-3
F
ML "B"
ML "A"
E
D
BL-1
BL-2
BL-3
BL-4
F
G
ML "B"
END VIEW
ML "A" & "B"
F
E
BL-1 & 4
D
BOTTOM VIEW
G
W
D
(T+R) OR "X"
BL-1
ML "A"
E
BL-2
(T+R) OR "X"
BL-3
ML "B"
F
BL-4
G
CUT DEVELOPED FROM FRONT VIEW
D
(T+R) OR "X"
E
ML "A"
(T+R) OR "X"
F
ML "B"
G
CUT DEVELOPED FROM BOTTOM VIEW
D
1/2 B.A.
E
1/2 B.A.
F
G
DEVELOPMENT USING CENTER OF BEND ALLOWANCE

Fig. 6:28

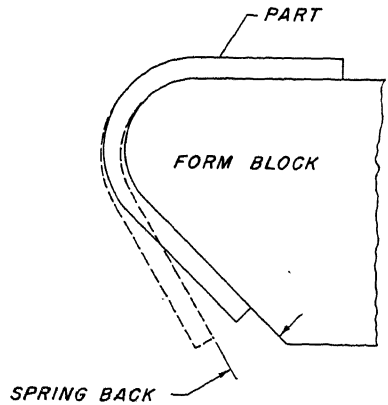


Fig. 6:29

difference between the permanent angle of bend and the maximum angle to which the material was forced, is known as "spring-back." This is a most important factor in the forming of materials in tempered condition, such as high-strength stainless steel or 24ST aluminum alloy. To secure the desired results when forming such materials, the form blocks used are designed to take into account the spring-back.

CHAPTER VII

TOOLS AND EQUIPMENT USED BY THE TEMPLATE MAKER

7:1 General.

A template man is a mechanic and as such he will naturally come in contact with the ordinary run of mechanics' hand tools and a few of the machine tools such as drills and drill presses, shears, punches, etc. At the same time he will be in general association with other types of mechanics using the more complicated and specialized equipment. He certainly will be a better craftsman and mechanic if he has a general understanding and knowledge of certain tools and how to properly use them.

The following discussion of hand tools is given for the sole purpose of assisting the junior template maker to more quickly orient himself.

In the majority of cases an aircraft company will specify the minimum tools required before a man is permitted to start work. Many companies have tool stores and will sell to employees at a nominal cost and on a time payment basis.

A good mechanic is one who has sufficiently good tools, not only for the immediate job, but also for the one job that is often just ahead. He buys a good grade of quality tools (never cheap tools) and generally patronizes one of the standard tool manufacturers. Last, but not least, he maintains his tools in good condition.

7:2 Files.

Files are named according to their shape. The files most commonly used by the template maker are the ordinary run of flat, round, half round, square, three cornered, and the vixen which may be either flat or half round.

A general classification of files may be made as follows: (1) Single cut; (2) Double cut; (3) Vixen. The first two may be still further classified as to arrangement or design of the cutting teeth as follows: (1) single-cut Bastard, second-cut and smooth; (2) single-cut Bastard and second cut. The Vixen files have specially deep cut circular teeth and are very useful. They are useful for rapid filing and smooth finishes on wood or soft metals such as dural, zinc alloy, lead, etc.

Grade.

Files are graded according to whether their cut is coarse or fine and the longer a file is the less teeth it will have per inch of length and it is therefore coarser accordingly. Files must be of equal length before you can really compare grades of cuts. The principal grades are rough coarse, bastard, second cut, smooth, and dead smooth. Rough files are generally single cut files and the dead smooth is double cut. Grades other than rough and dead smooth are made in both single and double cuts.

Cuts.

The cut of a file refers to the manner in which a file is made, i.e., teeth are machine cut on its edges or sides. Single cut files have parallel rows of teeth and the double cut have two sets of parallel rows of teeth which cross each other.

7:3 Draw Filing.

Draw filing is a shop term and refers to a finish operation which some mechanics frequently use. The file is grasped by both hands, one on each end, much the same as though it were a spoke shave or draw knife. Pushing and pulling the file in this sideways fashion, imparts a smooth finish and aids in fairing a long curve.

7:4 Hints on Filing Templates.

1. A file is a cutting tool and designed to cut as it is thrust forward, away from the body. Never use it backward or apply pressure on the return stroke.

2. Do not throw a good file in among other metal tools or miscellaneous iron or steel.

3. Be sure to use a file brush to keep your files clean.

4. Whenever possible clamp your work down firmly by either "C" clamps or spring clamps.

5. Do not permit the template to overhang the edge of the bench or other support. Too great an overhang may result in bending the template.

6. Hold the file firmly and use light long strokes applying an even pressure on the outward or downward stroke. Do not apply pressure on back strokes.

7. The file should be held at right angles (90°) to the flat surface of the template.

8. Watch your scribed line and do not undercut it. Try to file exactly to the center of the scribed line.

9. Never use a file without a handle.

10. Never use a file as a hammer.

11. Vertical filing is the customary practice among many template makers, i.e., the metal is clamped down to a bench top and filed vertically. See Fig. 7:1.

12. All cutting is done on the downstroke.

Fig. 7:1
Vertical Filing

7:5 Drills.

A template maker need not have a great deal of detailed knowledge concerning drills and drilling, but since he is a mechanic, he should be somewhat familiar with the subject because of its general application.

The smaller sizes of the twist drill will be most generally encountered. The following nomenclature describes a twist drill, shank-fluter, web, body, point, lips, heel, and shank which applies to tapered shank drills.

Shank: The round smooth portion which is clamped into the chuck of the drill motor or drill press.

Tapered Shank: A tapered shank is used on some of the larger drills when it is more desirable to secure the drill in a tapered holder rather than by a drill chuck. Most of the larger drills are of the taper shank variety.

Flutes: Two special grooves made in the body of the drill for the purpose of allowing the drill cuttings to escape from the point.

Web: The center or bottom portion of the flutes.

Body: The portion of the drill which extends between the shank and the point.

Point: The tapered or cone shaped portion of the cutting end of the drill.

Lips: The portion of the point which actually does the cutting operation.

Heel: The area of the point which lies behind the lips or cutting edges of the point.

7:6 Lubricants for Drills.

The template maker is concerned only with drilling small holes in soft steel or aluminum alloys. For steel, any light machine oil or lard oil, etc., is satisfactory. Aluminum alloys are quite often drilled dry because they drill very satisfactorily this way and also it is desirable to keep the surfaces of this alloy clean. Beeswax is sometimes applied to the drill point when drilling aluminum alloys to prevent clogging of the point.

In order to insure accurate drilling, drills must be sharpened correctly and proper drilling speeds used for the type of material being drilled. The best assurance of a correct point is by use of a drill grinding machine. Such a machine may not always be available so every man should be able to sharpen drills by hand on the grinding wheel. The following tips will enable one to more quickly acquire the art. (1) The average point must have from 10° to 12° lip clearance, i.e., the heel should be cut away (lower) than the point. (2) The lips should be of equal length and should be ground so that they will form equal angles with the central axis, the total angle to be as shown in Fig. 7:6—

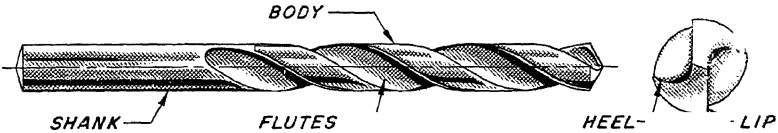


Fig. 7:2

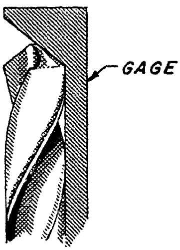


Fig. 7:3
Use of Drill Gage to Check Proper Angle

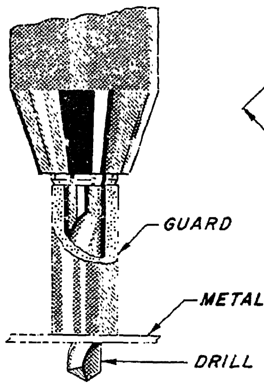


Fig. 7:4 Drill Guard

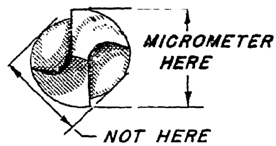


Fig. 7:5
Proper Place to Check Drill Size

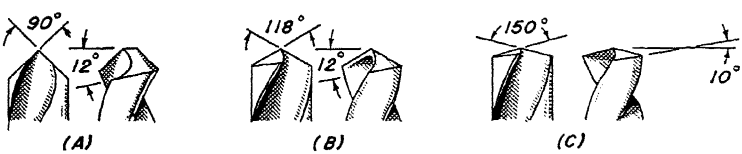


Fig. 7:6

A, B and C. When sharpening a drill, never force the grinding operation to the point of heating the drill excessively, and it is not advisable to dip a high speed drill into cool water for the purpose of cooling it. The best drill point angles used with various metals and metal thicknesses are shown in Fig. 7:6.

Fig. 7:6 (A) illustrates the best type of point for drilling soft materials such as wood, aluminum or magnesium alloys, soft steel, bakelite, etc., and is one that will center itself readily.

Fig. 7:6 (B) is a typical point used for drilling brass. The ordinary cutting edge as used on most drills will bite too deeply (called hogging) and chatter severely when drilling brass. This can be prevented by grinding a small flat face on the cutting

edge of the drill, i.e., decreasing the acute angle formed by the edge of the lip and the flute.

Fig. 7:6 (C) illustrates the recommended point for drilling such materials as the hard steels (chrome molybdenum, manganese, stainless, etc.).

When using the hand drill or the drill motor and drilling toward surfaces that are easily defaced use a rubber, fiber or wood block guard similar to the one illustrated in Fig. 7:4. Rubber tubing serves the purpose very well for aluminum and dural, while fiber or wood will suffice for steels and other harder materials.

7:7 Pilot Holes.

Pilot holes are small holes drilled in a part to act as a lead for a larger drill, counter bore, or fly cutter, etc. The average pilot hole for a larger drill should be at least less than $1/2$ the diameter of the larger drill. The final pilot hole for a counter bore or fly cutter should be just large enough to give proper clearance for the pilot used on those tools.

7:8 Fly Cutter.

A fly cutter is a tool which is sometimes used to cut out large diameter holes in flat parts or stock. It consists of a spindle which fits into the drill chuck. The spindle carries an adjustable cross arm which holds a cutting tool. The spindle has a pilot of a specified size attached to the end opposite the drill chuck.

The cutting tool and cross arm are adjusted to cut the proper diameter circle and the pilot is centered by the pilot hole which has been previously drilled in the part or stock. The fly cutter should be operated at fairly low speeds and a light feeding pressure.

7:9 Counter Bore.

A counter bore is a tool used for enlarging holes throughout a portion of their depth. They are so designated as to impart various shapes or angles to the bottom of the enlarged portion of the hole.

7:10 Surface Plate.

The surface plate is a flat plate of cast iron or mild steel machined to a smooth flat surface. Many of the better surface plates are heavily ribbed beneath the machined surface to prevent distortion or warping. A surface plate may be any size, the most

common size being 12 inches square, although sizes much larger and of shapes other than square are not uncommon. The uses of surface plates in a shop are many and varied, the most important being for checking flat surfaces or as a base from which to make measurements or setups for various hand or machine tooling operations and especially as a base when using height gages, sine bars, etc.

7:11 Height Gage.

The height gage is a vertical measuring instrument (usually an upright steel bar with a moveable head), used for finding or laying out of heights of various lines, holes, etc., on tools and equipment when measured from a base such as a surface plate. It is usually 10" to 18" in height, and graduated to read in thousandths of an inch by means of a vernier scale on the moveable head which slides up and down the upright bar.

7:12 Depth Gage.

The depth gage is used for measuring the depth of holes, recesses, slots, etc. There are two general types; one which consists of a head with a graduated bar sliding through it; the bar is graduated into ordinary rule graduations. The other is a micrometer depth gage which, as the name implies, is a gage which incorporates a micrometer in the head so that depths are measured in thousandths.

7:13 Slide Rule.

The slide rule is a mighty handy and valuable instrument to any draftsman, engineer or mechanic. It is a means of saving time and labor when problems in multiplication, division or proportion are involved and anyone having a fair knowledge of decimal fractions can learn to use the slide rule in from one to ten hours.

Many beginners steer shy of the slide rule because they think it is complicated. Many persons, who at first feared the slide rule, have suddenly, after a little application, found themselves a new thrill by discovering how to use this former mysterious device.

The slide rule is simply a series of specially constructed scales, one of which is moveable, laid side by side. To use the slide rule, one merely learns to read the various scales and place them in proper relation to each other and know where to look for the answer.

It is beyond the scope of this text to go into the details of learning to read the slide rule, but we do suggest that all students and mechanics get acquainted with it and learn to use it at the first opportunity.

7:14 Micrometer.

A micrometer is a mechanical measuring device especially designed to accurately measure widths, depths, and thicknesses in thousandths of an inch. According to its design, a micrometer may be used to measure the inside diameter of holes or widths of openings, the outside dimensions or thicknesses of parts or the depth of drilled or bored cuts, etc. It is a tool that nearly everyone who works around a shop or drafting room will be concerned with and a beginner should not pass up an opportunity to get acquainted with its operation and uses.

All micrometers have one general or common characteristic which is a threaded spindle having **forty threads** (40) per inch, and adjustable through a distance of one inch.

Because of the fact that a micrometer spindle is threaded forty threads per inch, the spindle must be revolved **forty times** before it travels through the **distance of one inch.** Since we desire to measure in thousandths and we are concerned with the inch as a basis of measurement, we must work on the fact that there are 1,000 thousandths in one inch, therefore the spindle will travel $\frac{1}{40}$th of its total possible travel of one inch (1000/40) or .025 every time it revolves once. Therefore, the barrel is marked throughout its length in graduations of .025 of an inch with each major division of .100 of an inch numerically stamped upon the barrel, i.e., 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, etc. In order to read the limits of travel in thousandths, (.001, .002, etc.) as the spindle travels through one complete revolution or .025, the thimble, which fits over the spindle and is an integral part of it, has its circumference graduated in thousandths (.001 to .025). In short, to read a micrometer one must know the total number or partial number of revolutions the spindle has made after it has moved away from zero position. For example, if one minor division has been passed on the barrel and three on the thimble, the micrometer reading would be .028.

7:15 Shears and Snips.

Numerous kinds of hand lever operated shears and hand snips are used for cutting the template from metal stock. There are two general types of hand lever operated shears: (1) The "Scroll

Shear" which is a deep throated shear. The deep throat permits quite large sheets of metal to be handled. (2) A throatless type is also commonly used where cuts are not too far in from the edge of the metal. Some template departments make use of power metal cutting band saws or high speed power, punch type cutters, similar to a nibbler.

Template makers will find a good pair of husky hand tin shears very useful. Also a special pair of snips is available at most aviation supply houses or tool stores at the various factories. Two pairs of snips, one a right hand and the other a left hand, are used for cutting out right and left hand circular arcs or curves, etc. See Fig. 7:7.

7:16 Scribe.

A scribe is any pointed instrument which can be used to scribe lines and layouts on various surfaces. Any short piece (prefer-

Fig. 7:7
Use of Scribe

ably 1/8 or 3/16" round) of tool steel properly hardened and ground to a pointed end will serve as a scribe, but anyone of the commercial makes with removable points will give better service and create more pride of ownership in good tools and hence better craftsmen. Fig. 7:9 illustrates correct and incorrect types of points for scribes. The correct point is not flat or blunt, but a finely tapered point which will materially aid in making accurate scribe lines. Fig. 7:7 illustrates proper use of scribe when scribing around the edge of a template or along a steel rule, etc. If incorrectly used, the scribe point will trace a wavy line or one that is too far away from the rule or template.

7:17 Triangles and Straight Edges.

Celluloid triangles, rules and straight edges are not used in the shop when used in conjunction with scribes and other shop tools because the soft edge would soon become marred and inaccurate. Metal triangles and steel rules are used.

7:18 Splines and Curves.

A spline is a flexible strip of material such as pyralin, wood, etc., and used to produce a long faired line through a series of refer-

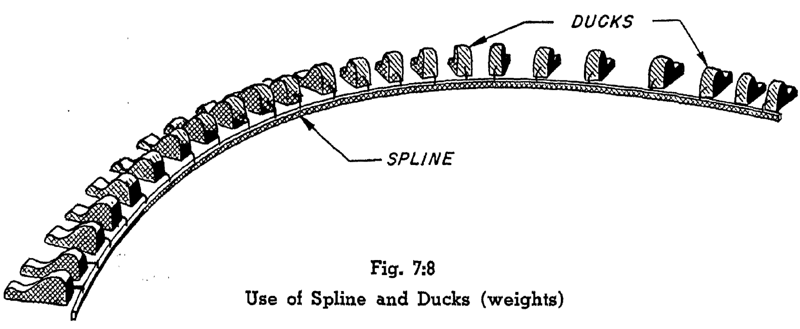


Fig. 7:8
Use of Spline and Ducks (weights)

ence points established for that purpose. See Fig. 7:8. A French curve or an irregular curve is utilized for the same general purpose as a spline except that the curves are generally shorter and applied to shorter lines and sharper curves. The spline is bent and held to the desired curve by means of "ducks" which are specially shaped weights, (usually lead).

7:19 Protractor.

There are many kinds and types of protractors, but the metal

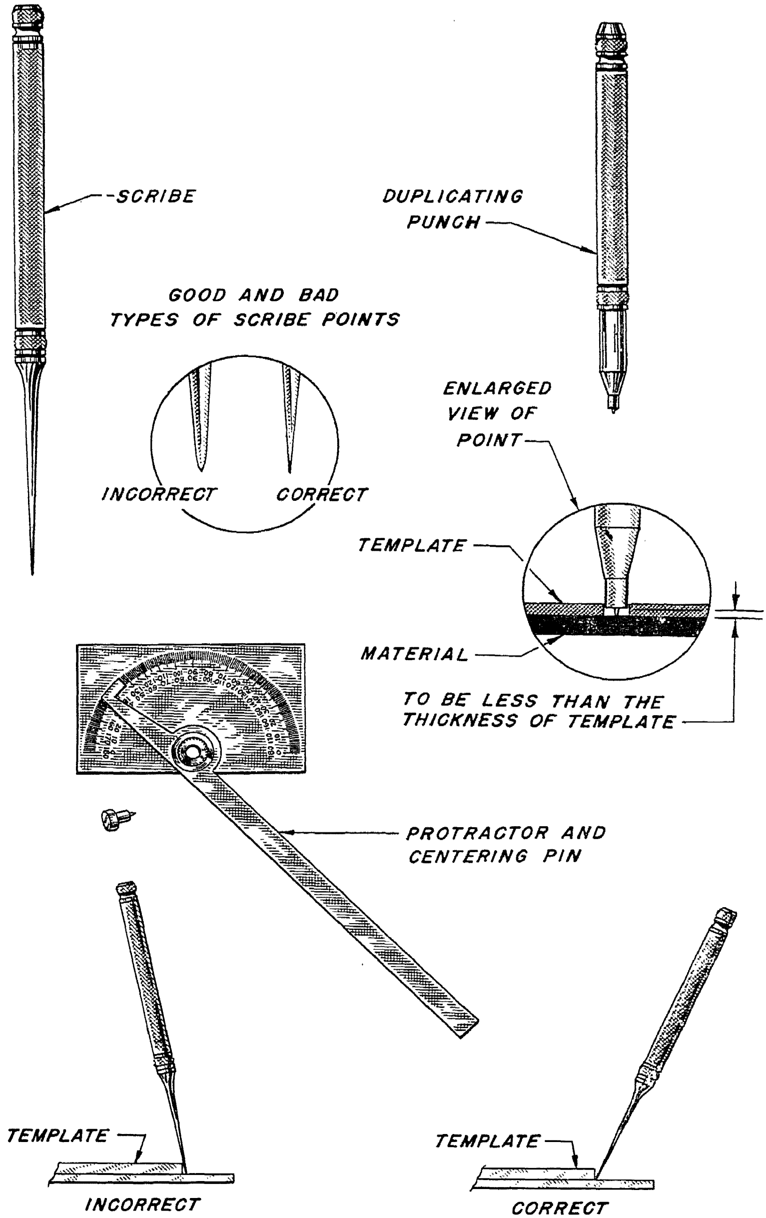


Fig. 7:9 USE OF SCRIBE

protractor having an adjustable arm is the one most commonly used. A preferred type is shown in Fig. 7:9. It has one edge of the blade in line with the center or pivot point and degree markings on the head. This protractor also has a hollow pivot bearing on a centering pin which permits accurate alignment of the center with a hole or center punch mark.

7:20 Whitney Punch.

The Whitney Punch is the manufacturer's name for one of several types of metal punches. There are two general types: (1) a small hand squeezer punch with interchangeable punches and dies and (2) a larger machine incorporating multiple punches and dies arranged on a circular carriage in such a manner that any one of the punches may be operated by a short hand lever. The chief use which the template maker will have for this tool is for cutting out small radii.

7:21 Squaring Shear.

As it is necessary to have straight edges and square corners on template stock, a squaring shear is very useful in the template department. The most commonly used machine is one having a straight edge cutting blade, approximately four feet long, operated by a foot treadle. A much larger power driven cutting shear is used in production departments for making much longer and heavier cuts for shearing off strips of metal used for production of parts. See Fig. 7:10.

7:22 Duplicating Punch.

This is a special punch used for transferring the centers of holes from templates to stock or parts. A typical duplicating punch is illustrated in Fig. 7:15. When using this punch, make sure it is always held at right angles to the flat surface of the metal and tap it lightly with the hammer. This type of a punch should have a fine center punch point as quite frequently it is necessary to use these duplicated hole centers as centers for scribed holes or radii, etc.

7:23 AN-AC Standards.

Many parts such as bolts, nuts, screws, rivets, and washers have been standardized by the U.S. Army and Navy. Such standards or

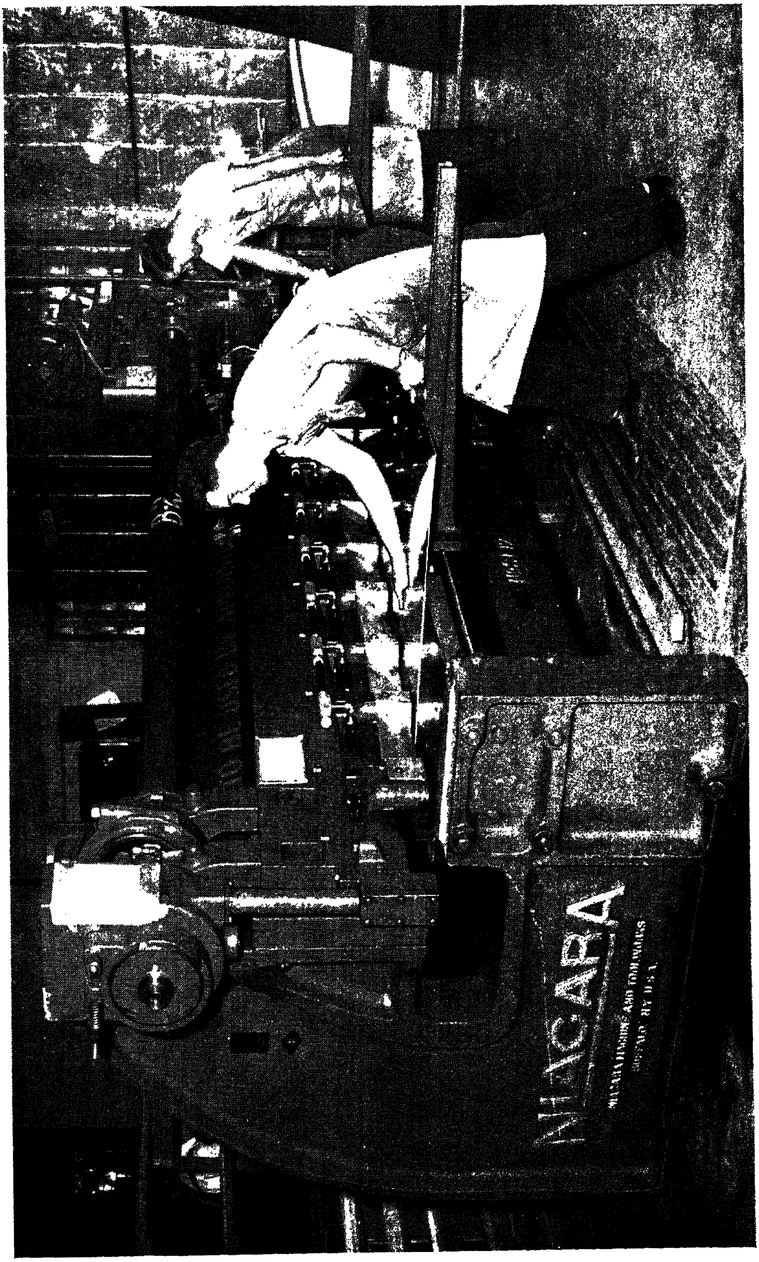


Fig. 7:10
Power Shear

specifications are known as (AN) meaning Army and Navy. When the Army alone has standardized a part, it is known as Air Corps specifications, or (AC).

An organization known as the National Aircraft Standards Committee is doing a great deal of excellent work on establishing more complete and effective standards for the aircraft industry.

A detailed discussion of AN or AC specifications is not warranted in this book and the template maker will not have immediate or urgent need for specific use of them. He should however, examine an AN standards book at his earliest opportunity.

CHAPTER VIII

TYPICAL AIRCRAFT PARTS AND THEIR FLAT PATTERN DEVELOPMENTS

8:1 General.

Before proceeding directly into the specific details of developing templates for actual parts, it is perhaps best to offer several helpful suggestions, a few precautions, and a somewhat general statement of facts regarding the drawings of parts and their flat pattern developments, which take up the major portion of this chapter.

The parts chosen for flat pattern development are actual parts from an aircraft factory and were particularly selected because they presented examples of all the essential problems confronting a template maker.

The title blocks used on the drawings of parts are typical engineering title blocks, and those appearing on the developed flat pattern are of a general nature.

No attempt has been made to enter information in all the spaces of the title block, because the template man does not require the omitted information concerning calculated weight, actual weight, heat treat, finish, etc.

The caption "OPP. HAND" refers to parts which are similar or practically identical (two parts, right and left hand, used on the same airplane). The only difference in the two parts is that formed parts have flanges which are bent in opposite directions. When two parts are required and no comments are made as to right and left hand parts, it is assumed that the left hand part is shown in the drawing.

Unless otherwise noted, the scale is assumed to be full scale. There is no scale noted on the drawings used because the originals were full scale and on regular A size (8½x11) drawing sheets, but were subsequently reduced approximately one half to meet the page dimensions of this text.

In order that the student may benefit from pertinent comments and suggestions regarding his work, he should leave the path followed, in solving the problems, exposed to view. This may be accomplished in two ways: First, all construction lines should be drawn in accurately and lightly and not erased; second, all computations should include formulas and all operations should be

shown step by step. This will enable the instructor, who may be considered in the role of an inspector, to call attention to the definite points of departure from a correct construction or a correct solution.

A wrong answer may be the result of an error in interpretation, or an error of carelessness. The first requires a more thorough understanding of the situation involved; the second, more care in performing a simple operation.

8:2 Information Given On Templates:

A template does not necessarily have all the information on it which is required to make the part. (This is only a matter of opinion and varies with different manufacturers.) But a good template will eliminate, in most cases, any measuring or figuring of locations of holes, the beginning and ending of bends, slots, and outside contour dimensions.

The main reason for not putting everything on the template is to simplify the template so that one can see at a glance the main development of the part in the flat.

If the information as to the size of each hole, bend radius, gage of material, etc. were all given on the template, it not only would add more confusion to the workman; it would also be a duplication of the same information given on the blueprint.[9]

Also in case of a minor change when the size of a hole, either a rivet hole or a lightening hole, is changed and when the center remains the same, this change will not require that the template be changed because the size of the hole is given on the blueprint only, while just the center location is given on the template.

8:3 Blueprint Reading:

On receiving a blueprint the first step is to read the print carefully, bearing in mind the type of template required. Make sure it is the latest print and up-to-date as to changes.

Blueprint reading for template work is entirely different than for checking an assembled or finished part.

The template man must be able to picture in his mind the part unfolded and flat. This type of blueprint reading is not any more difficult than the ordinary blue print reading where one pictures the part bent up and finished. But until one has had the experience and practice, this will be one of the main difficulties en-

[9] Although this seems to be advisable in some cases where the template is large enough and rather simple and where the blueprint is an extremely large and complicated one.

countered. This type of blueprint reading is the first and most important part of template making. An experienced man will be reading the print and in his mind developing and visualizing the part in the flat without giving it a thought as to why and the better a man can do this, the better template man he is going to be.

8:4 Practical Hints for the Template Maker.

DO'S

1. Remove all paint and dirt before sending parts to the spotwelder.
2. Clamp all parts, to be spotwelded, securely in place.
3. Plug small unwanted holes with a steel rivet made from welding rod and spot weld if possible. If the hole is slightly countersunk from both sides, the plug will stay in better.
4. Cover up mis-drawn scribe lines with paint.
5. When checking a spline for a smooth curve, raise and lower one duck at a time until the spline does not move when any one duck is removed.
6. Use plenty of ducks.
7. Hold all punches, drills, etc., perpendicular to the metal.
8. Use care in cutting inside radii so as not to bend or distort the template.
9. Transfer dimensions with a pair of dividers and trammels whenever it is possible, rather than by rule.
10. Allow the drill point to center itself in the template which is to be drilled before you start the motor.
11. Remove all burrs from the drilled holes. A good burring tool may be a large drill or a metal countersink. Caution: Do not burr excessively.
12. Cover the working edges of all clamps, vises, etc., with masking tape to keep the templates from being scratched.
13. Check your tools occasionally especially the rules and triangles.
14. Be sure you are working with the latest or up-to-date blueprint.
15. Recheck any and all computations.
16. Read the blueprint carefully before starting to work. Visualize your problem before starting in. Sometimes a part that is difficult to visualize will become easy if a piece of paper is folded so as to resemble the part.
17. Recheck all dimensions, locations of pilot and pin holes, etc., before turning a job in as complete.

DON'TS

1. Splices in templates are undesirable. Splice only when necessary.
2. Don't use rivets in splicing if you can use a spot weld.
3. Don't make a butt spot weld joint without approval of supervisor.
4. Don't make a solder joint without approval of supervisor.
5. Don't measure from the end of the rule. If the graduations start at the extreme end of the scale, start measuring from the one-inch division, but be careful not to read the total measurement one inch too large.
6. Don't hit steel numeral or lettering stencils too hard (especially on small templates as they may warp out of shape).
7. Don't cut into a new sheet of metal unless there isn't a smaller piece available.
8. Don't clamp the template too tight when clamping to the bench, as the template may be warped or bent out of shape.
9. Don't throw scrap material on the floor. Use scrap box.
10. Don't let a template extend over the edge of the work bench unless ample caution is taken to prevent other people from bumping into it.
11. Do not make mistakes in the transposition of numbers; e.g., when reading the dimension 1.187. Do not read it as .187.
12. Don't forget to check your work before turning job in to inspection.
13. Do not scratch template stock or any metal which is to be used in aircraft construction.

CAUSES FOR REJECTION BY THE INSPECTION DEPARTMENT

1. Template maker placed wrong identifications on the template.
2. Template made wrong because obsolete print was used.
3. Blueprint was misread.
4. Wrong dimensions used.
5. Angles and lengths of lines wrong because they were miscalculated.
6. Pilot or pin holes miscalculated.

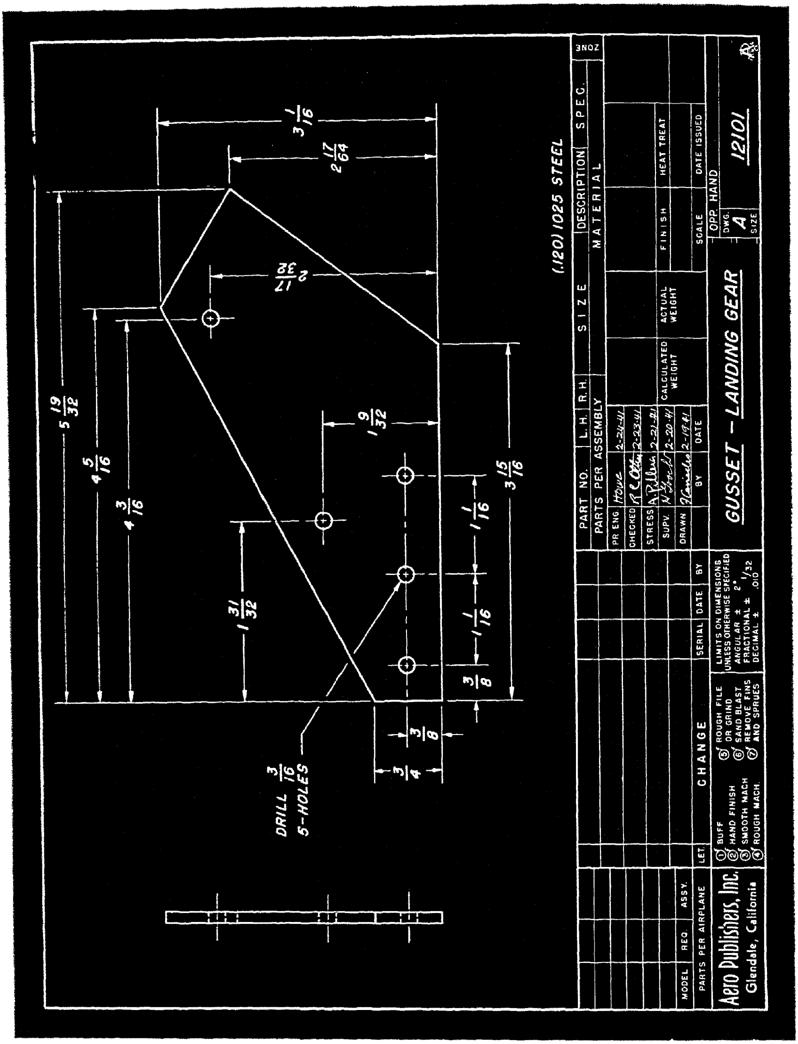
Through the courtesy of the Lockheed Aircraft Corp., Burbank, Calif., the following blueprints of typical aircraft parts have been made available for use in this text.

PROBLEM INDEX

Problem No. 12101

Title:

Gusset—Landing Gear.

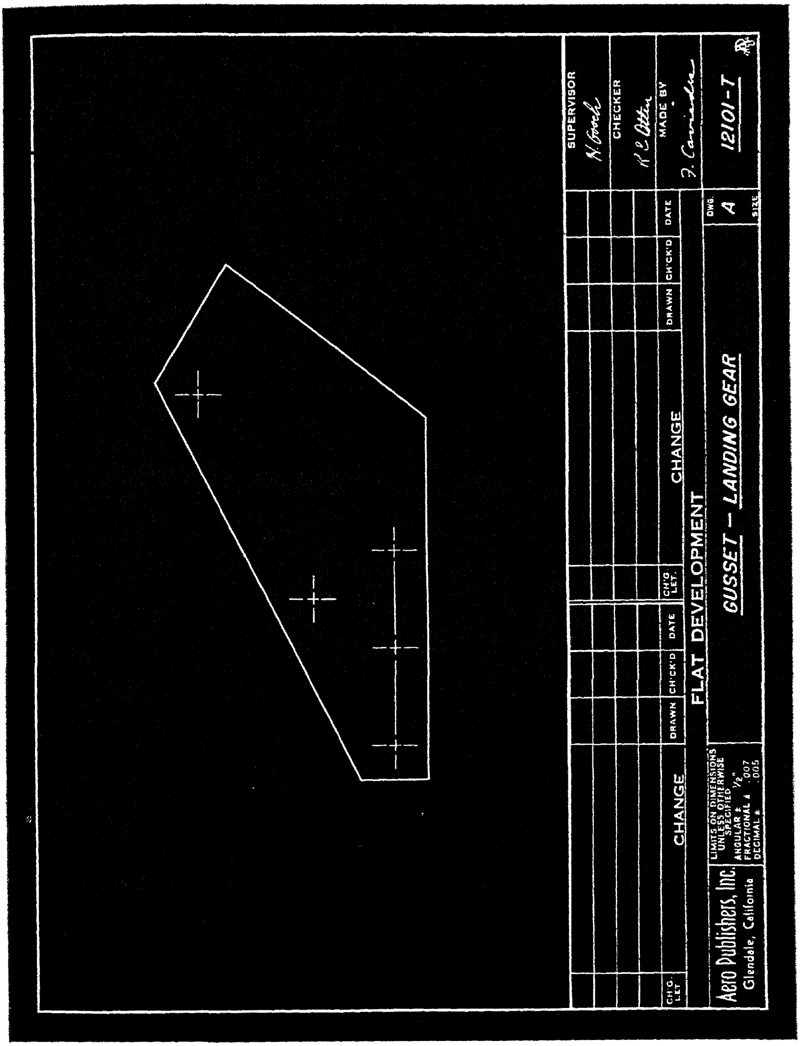


Object:

To lay out a template by location of points and straight lines drawn between these points.

Procedure:

Draw a horizontal and a vertical line near the lower left-hand corner of the layout material. From these two reference lines, lo-



cate the points of the five corners of the gusset by using the dimensions that are given on the blueprint.

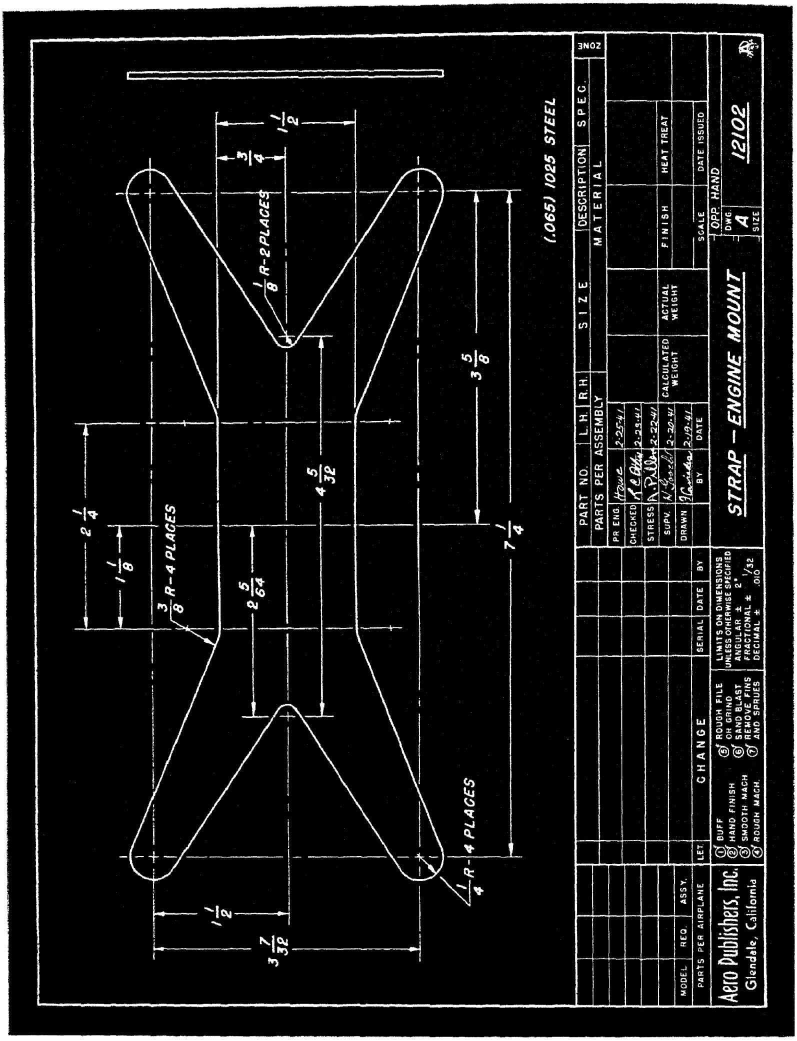
Connect all points with straight lines.

(Continued on page 248)

Problem No. 12102

Title:

Strap—Engine Mount.

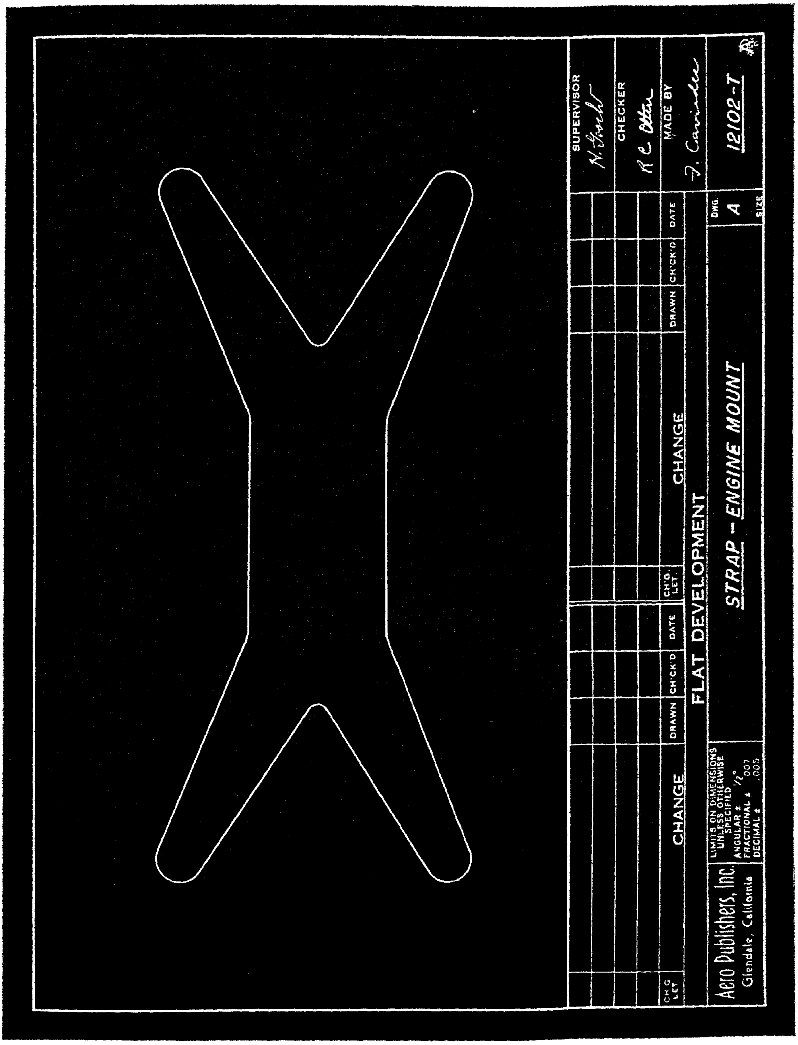


Object:

To lay out a template by location of radii centers and straight lines drawn tangent to these radii.

Procedure:

Draw a vertical and a horizontal reference line near the center of the layout material. The vertical reference line shall be used as



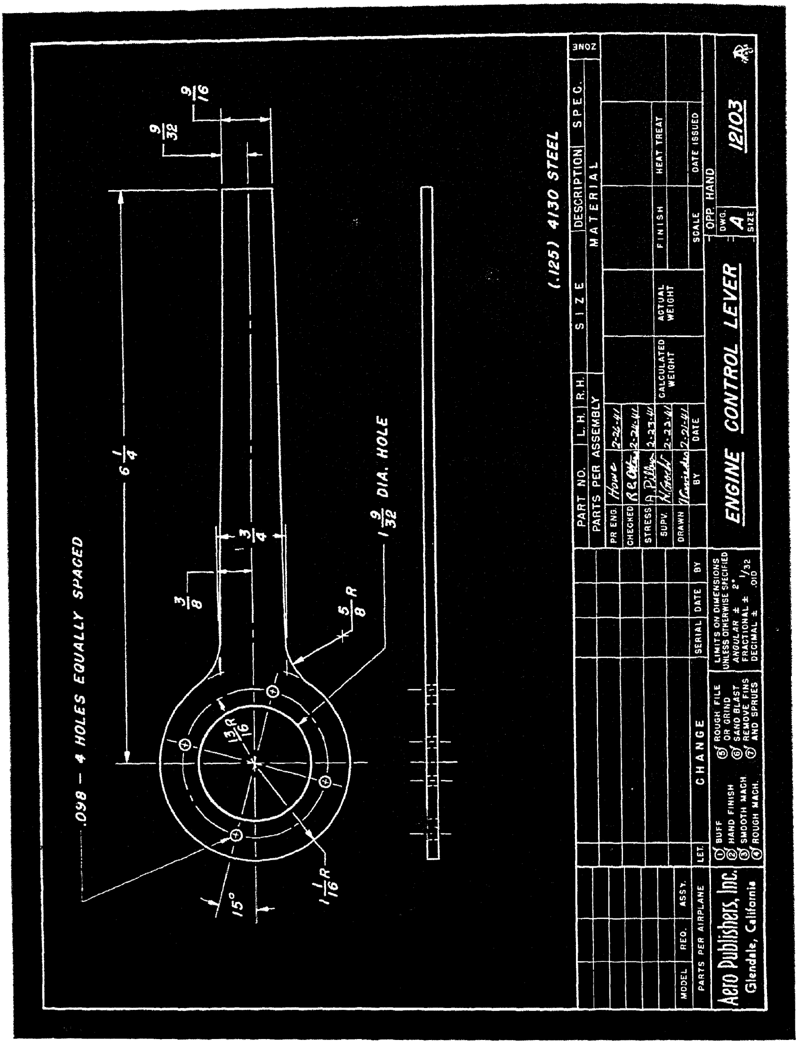
the vertical center line of the strap and all horizontal dimensions will be measured from this line. The horizontal reference line will be used as the horizontal center line which passes through the cen-

(Continued on page 248)

Problem No. 12103

Title:

Engine Control Lever.

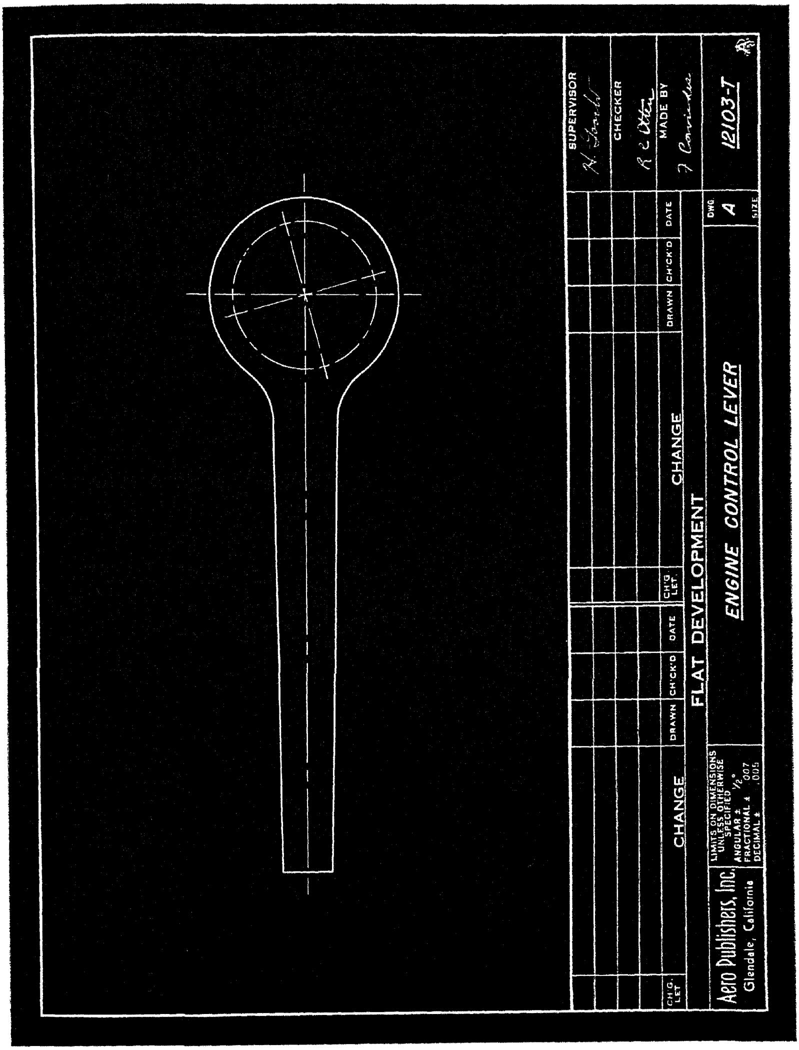


Object:

To lay out a template having tangent radii.

Procedure:

Draw a horizontal and a vertical center line and at the intersection of these lines draw two circles of $1\frac{1}{16}''$ and $\frac{13}{16}$ radius.

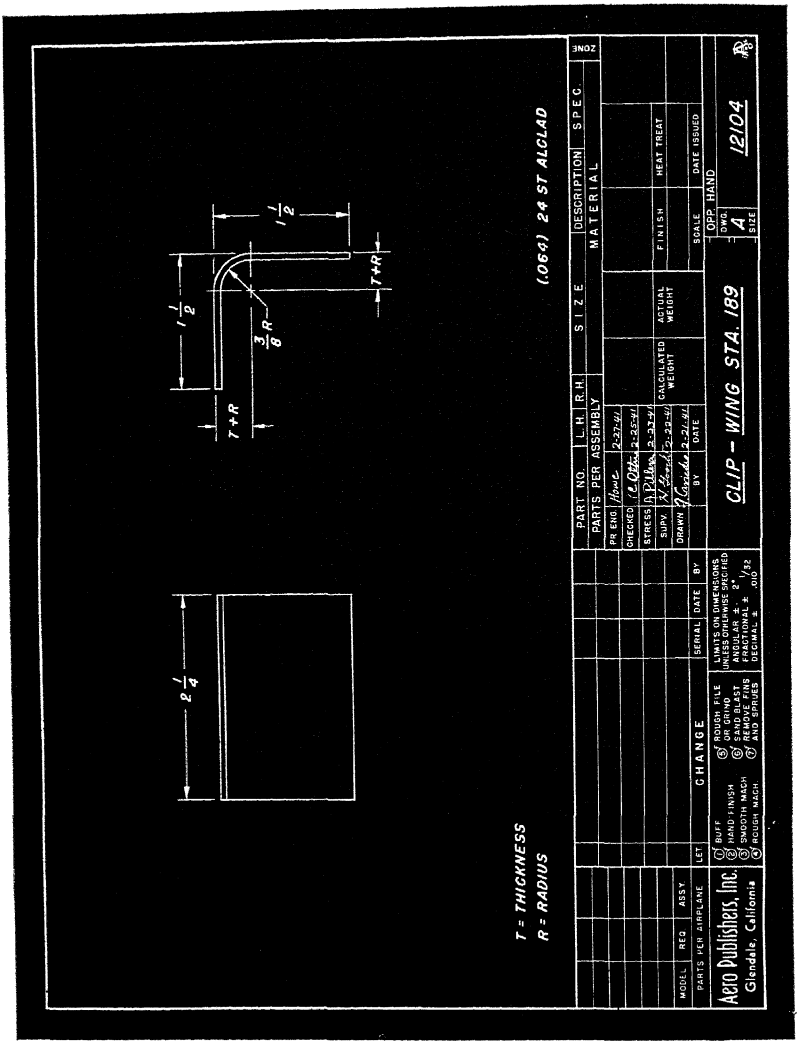


Look at the print closely and you will see that the handle is $\frac{3}{4}''$ wide at the point where it would intersect the $2\frac{1}{8}''$ diameter circle if it were continued in a straight line. The handle tapers in a

(Continued on page 248)

Problem No. 12104

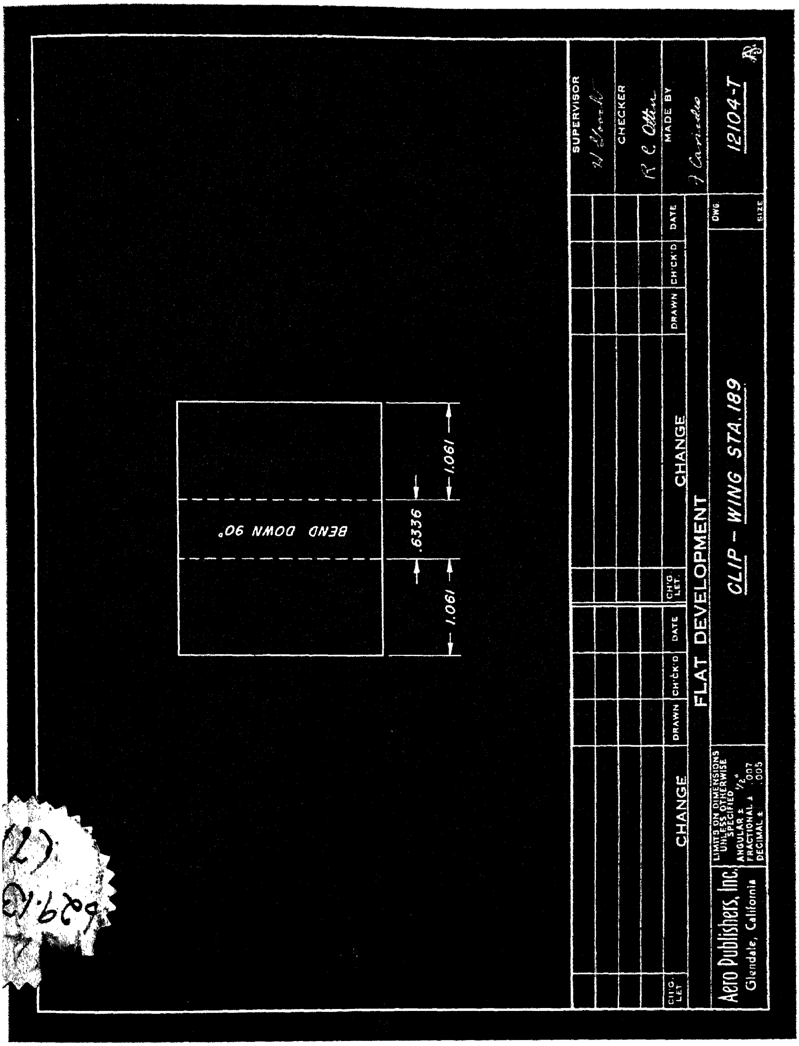
Title:
Clip—Wing Sta. 189.



Object:
To develop a template for a part having a single 90° bend.

Procedure:

The developed template will be $2\frac{1}{4}''$ in width and the approximate length can be determined by adding the two $1\frac{1}{2}''$ dimen-



sions.

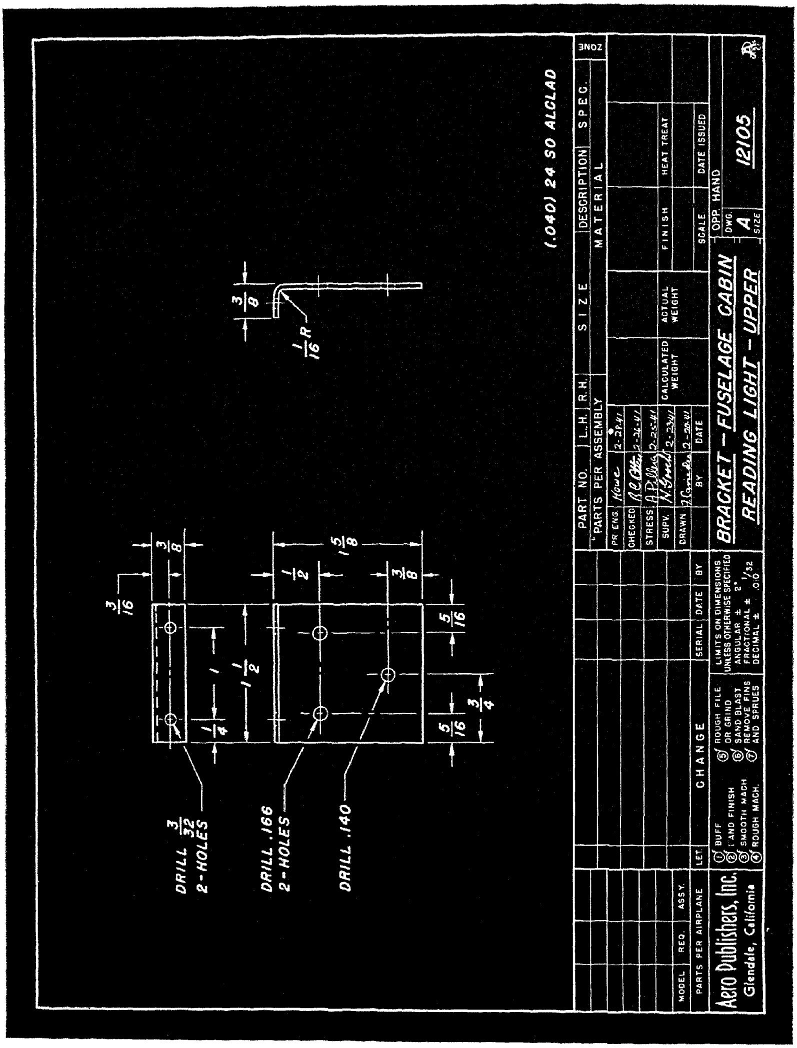
Draw two vertical lines $2\frac{1}{4}''$ apart, and a horizontal line crossing the two vertical lines. The first bend line will be drawn parallel

(Continued on page 248)

Problem No. 12105

Title:

Bracket—Fuselage Cabin Reading Light—Upper.

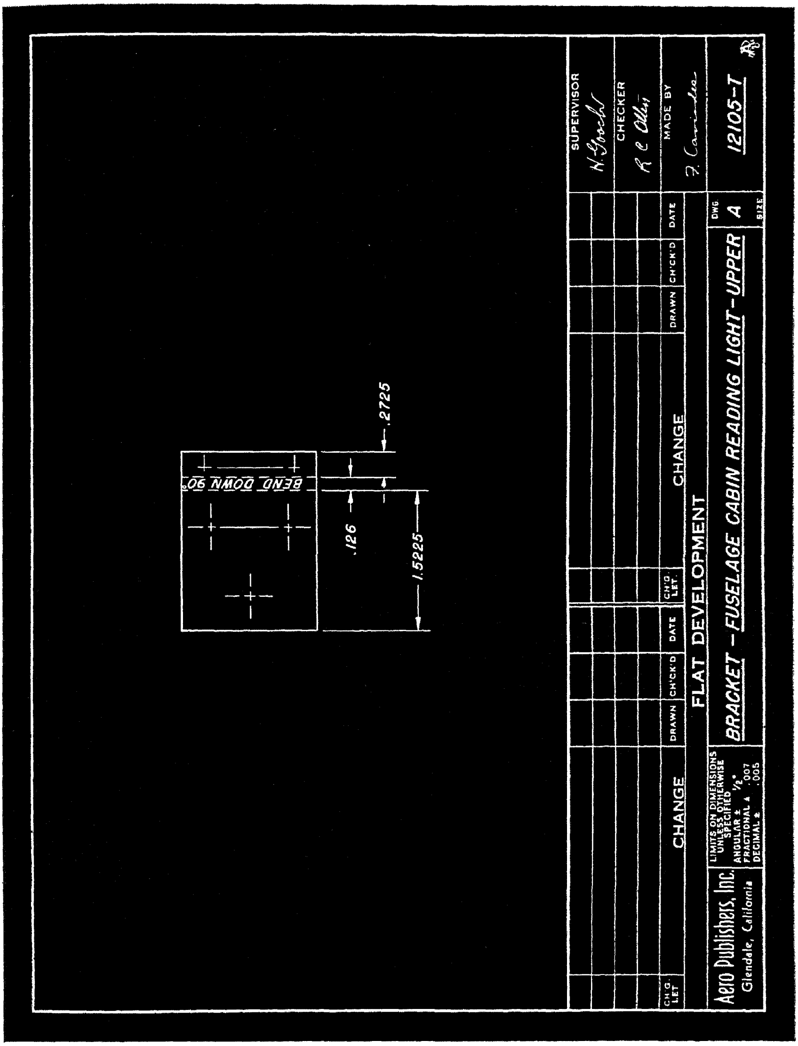


Object:

To develop a template for a part with a single 90° bend and having holes which are located from the mold line.

Procedure:

The relationship of mold lines to bend lines is outlined in Chapter 6.

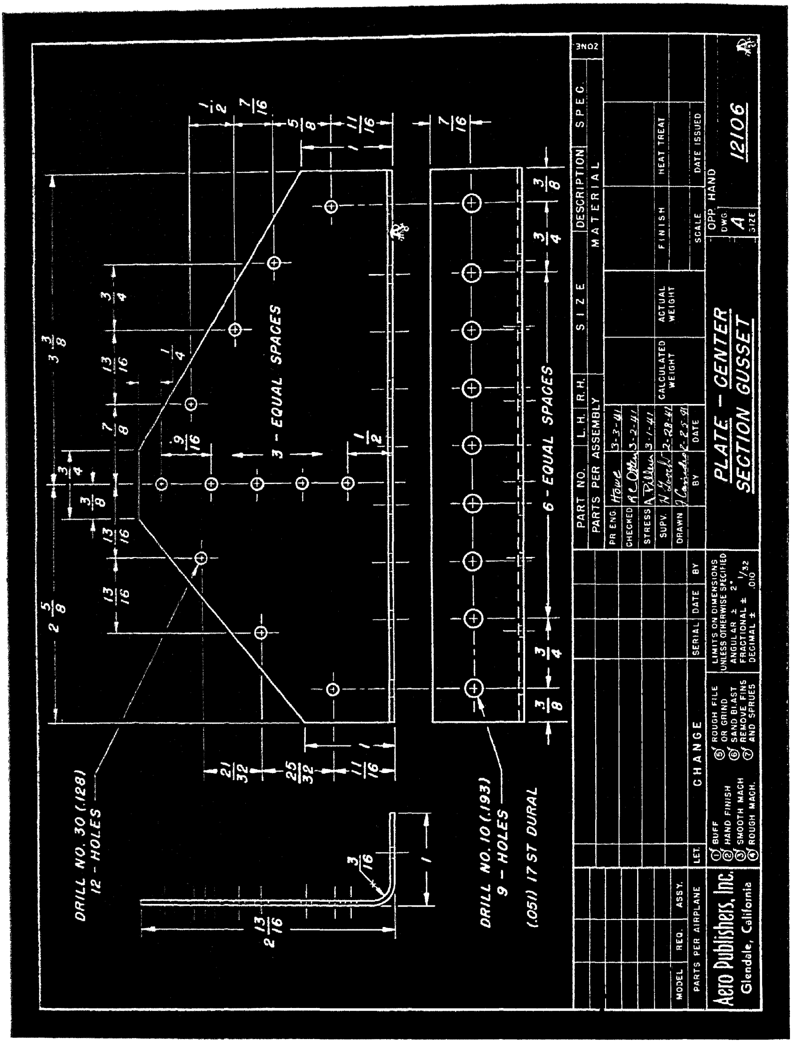


The finished template will be 1½" in width and approximately 2" in developed length. Draw two vertical lines 1½" apart. A horizontal line crossing the two vertical lines will become the lower

(Continued on page 248)

Problem No. 12106

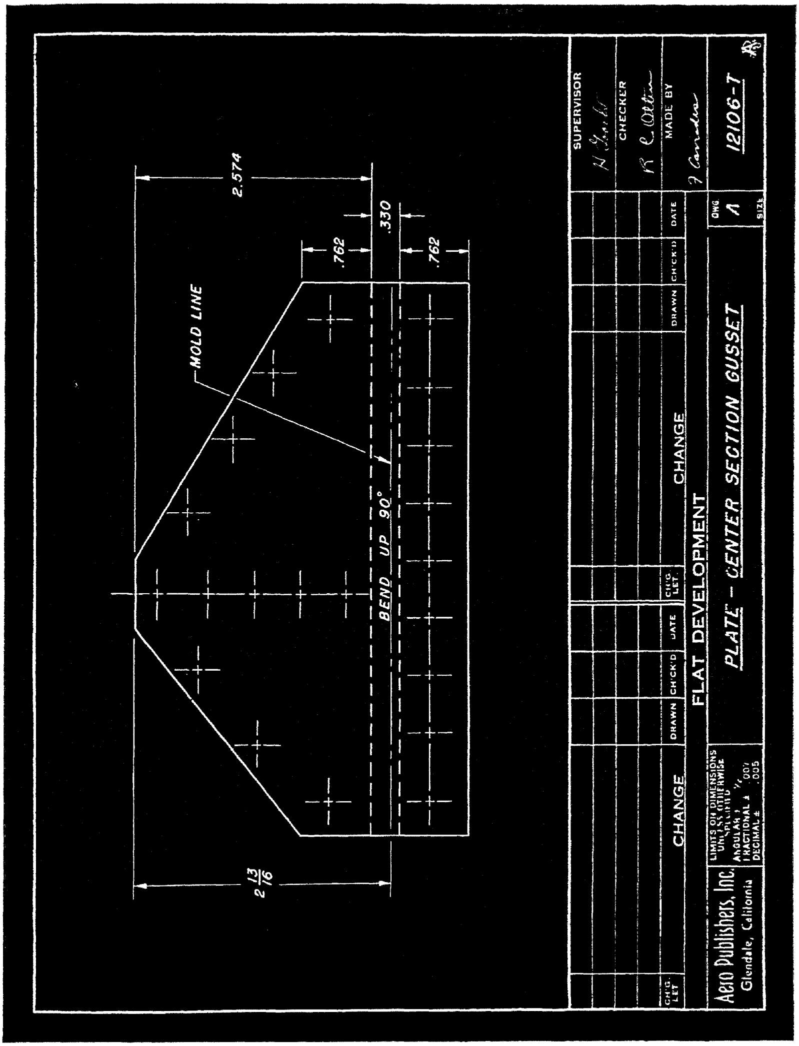
Title:
Plate—Center Section Gusset.



Object:
To develop a template for a part which has a 90° bend with varied hole locations.

Procedure:

Finished template will be 6" long and approximately 4" wide. The template should be developed along the lines as previously



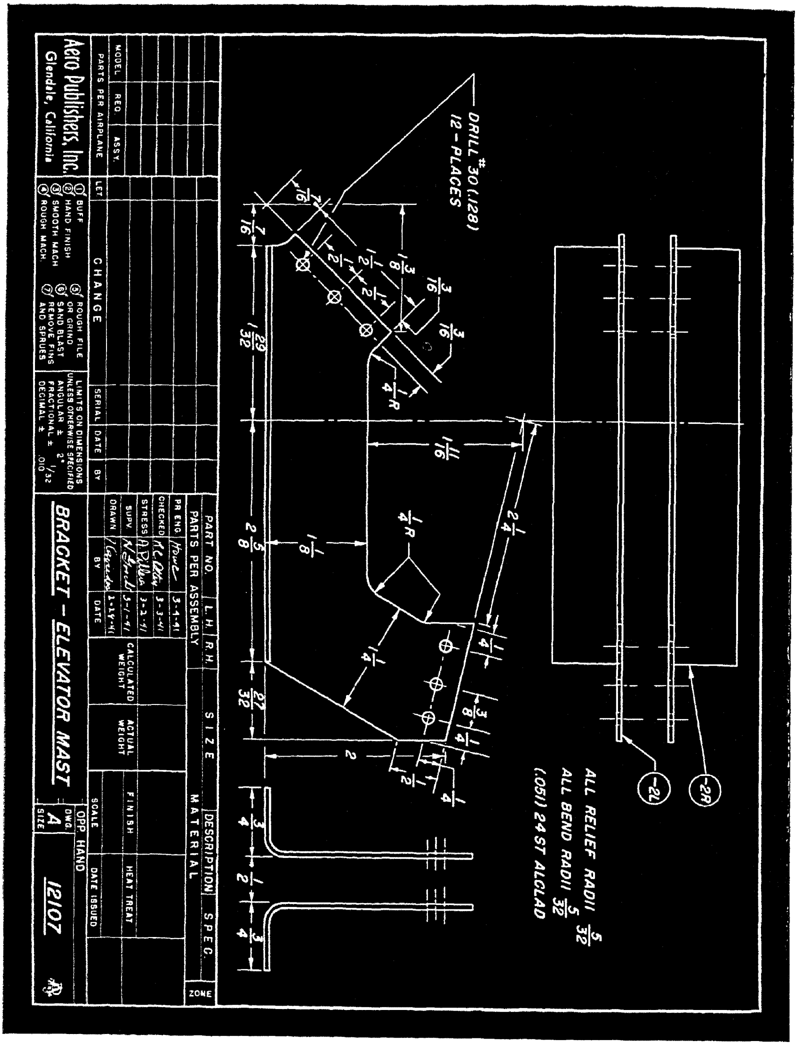
described for any part having a single 90° bend. The reference mold line should be drawn in its proper relationship to the bend lines. See Chapter 6. This mold line is drawn on the template to

(Continued on page 249)

Problem No. 12107

Title:

Bracket—Elevator Mast.

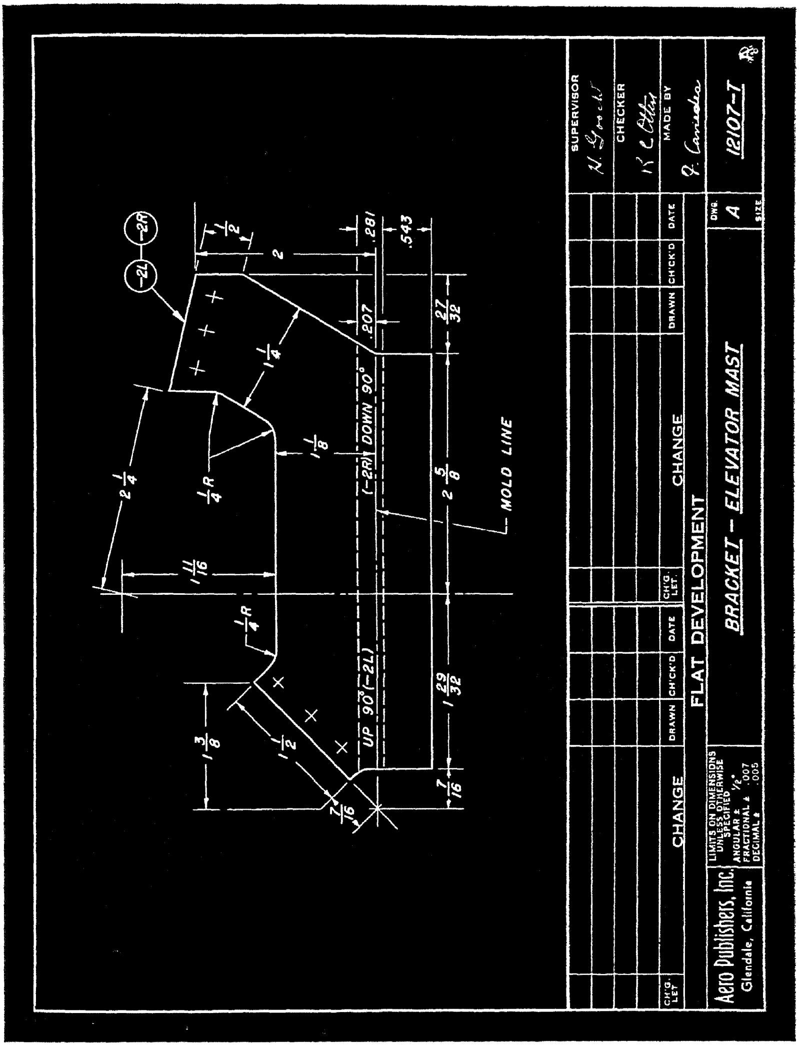


Object:

To develop a template for two parts similar to each other except for direction of bend.

Procedure:

Draw a horizontal mold line and a vertical reference line. Using dimensions given on print, complete outline, also locate holes in



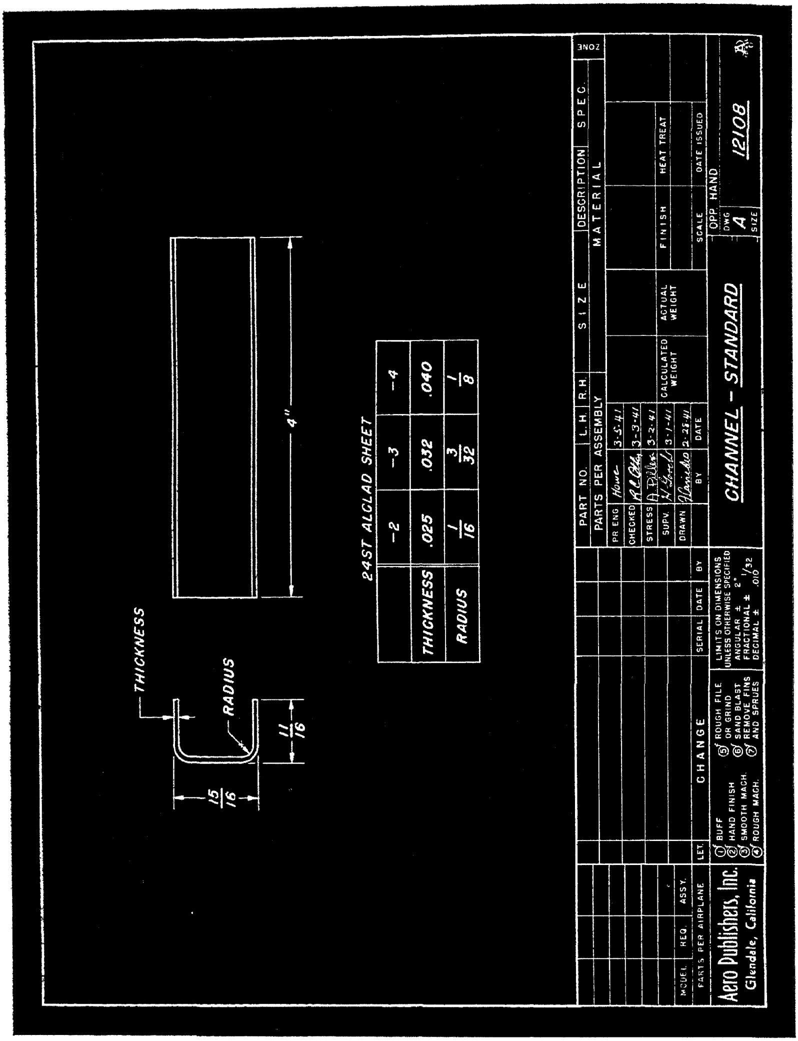
flat pattern. Notice that flange has been dimensioned on horizontal mold line of front view, therefore, both ends of flange will be located from this horizontal mold line. Direction of bend should

(Continued on page 249)

Problem No. 12108

Title:

Channel—Standard.

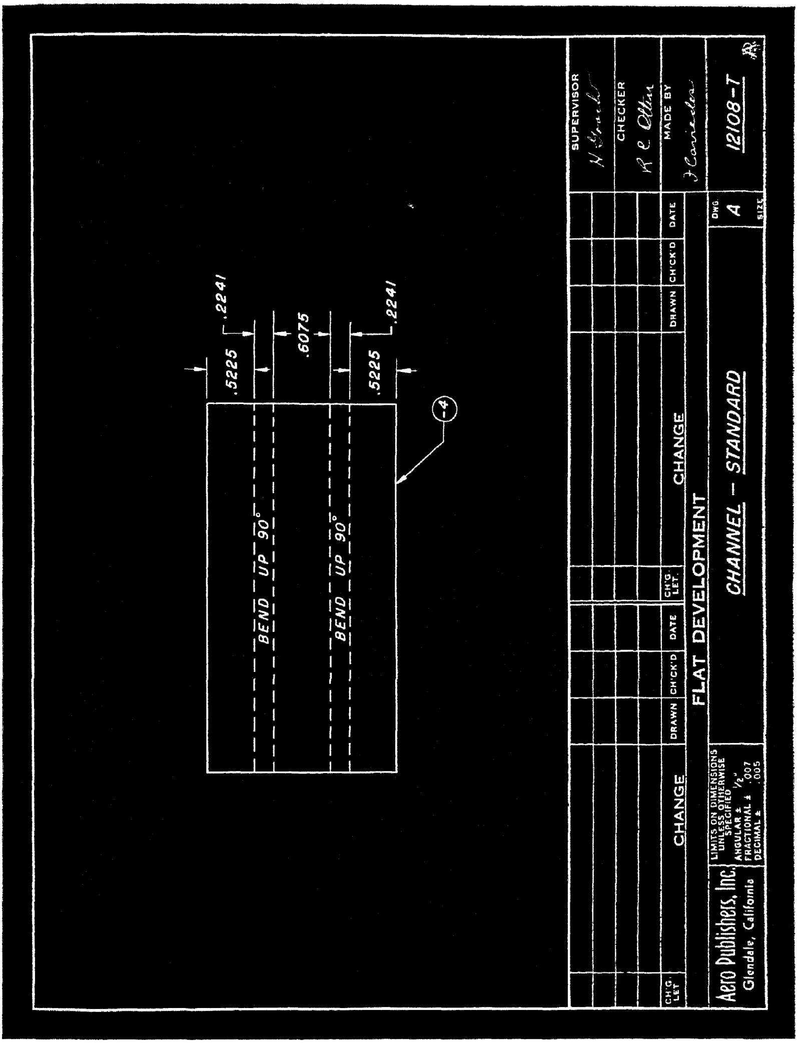


Object:

To develop a template for a part having two 90° bends and to be able to understand the use of tabulated information on drawings.

Procedure:

As this drawing specifies three distinct thicknesses of metal of which this particular channel can be made, it is necessary to pre-



determine which template is to be developed.

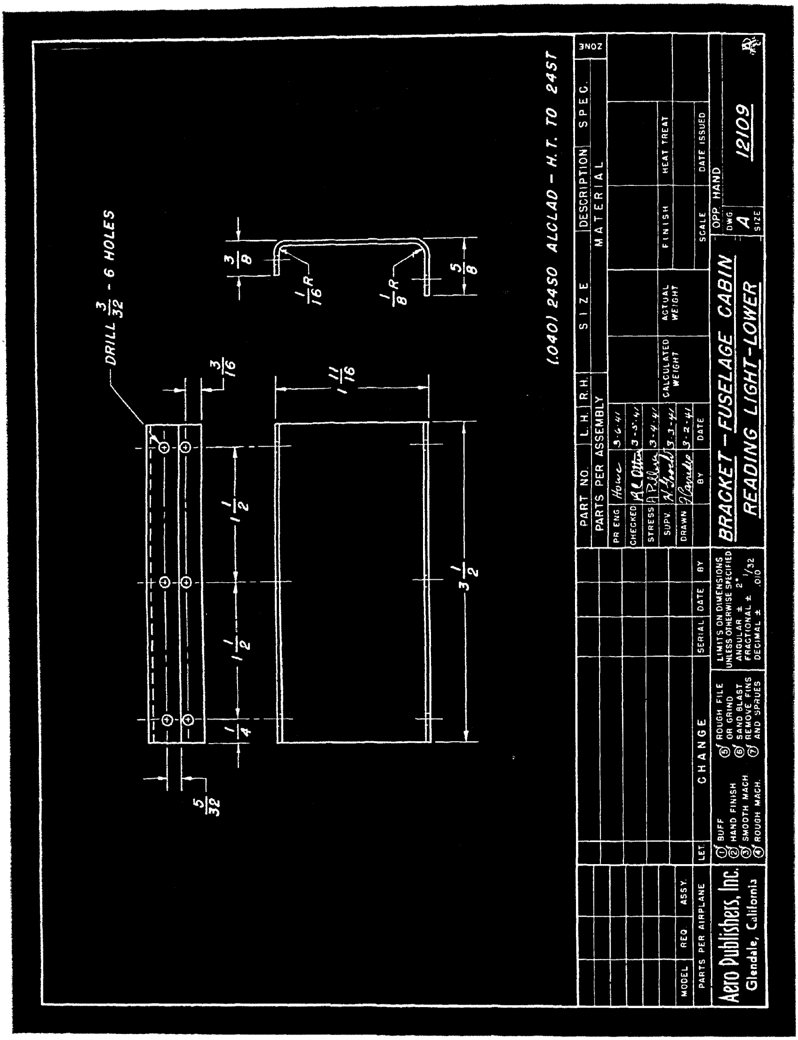
The standard practice among many factories calls for certain standard channels or angles under the following manner.

(Continued on page 249)

Problem No. 12109

Title:

Bracket—Fuselage Cabin Reading Light—Lower.

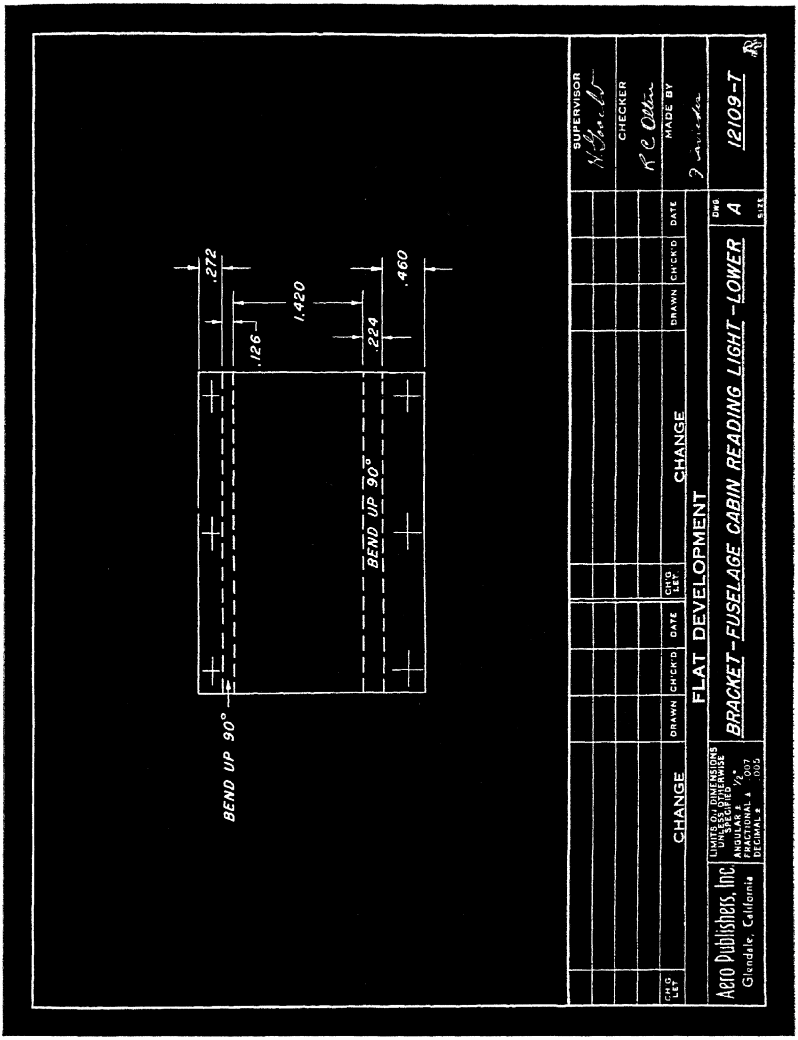


Object:

To develop a flat template for a part having two 90° bends with different bend radii.

Procedure:

Procedure for developing the width of this channel is the same as for Problem 12108, except that the portion between the bends

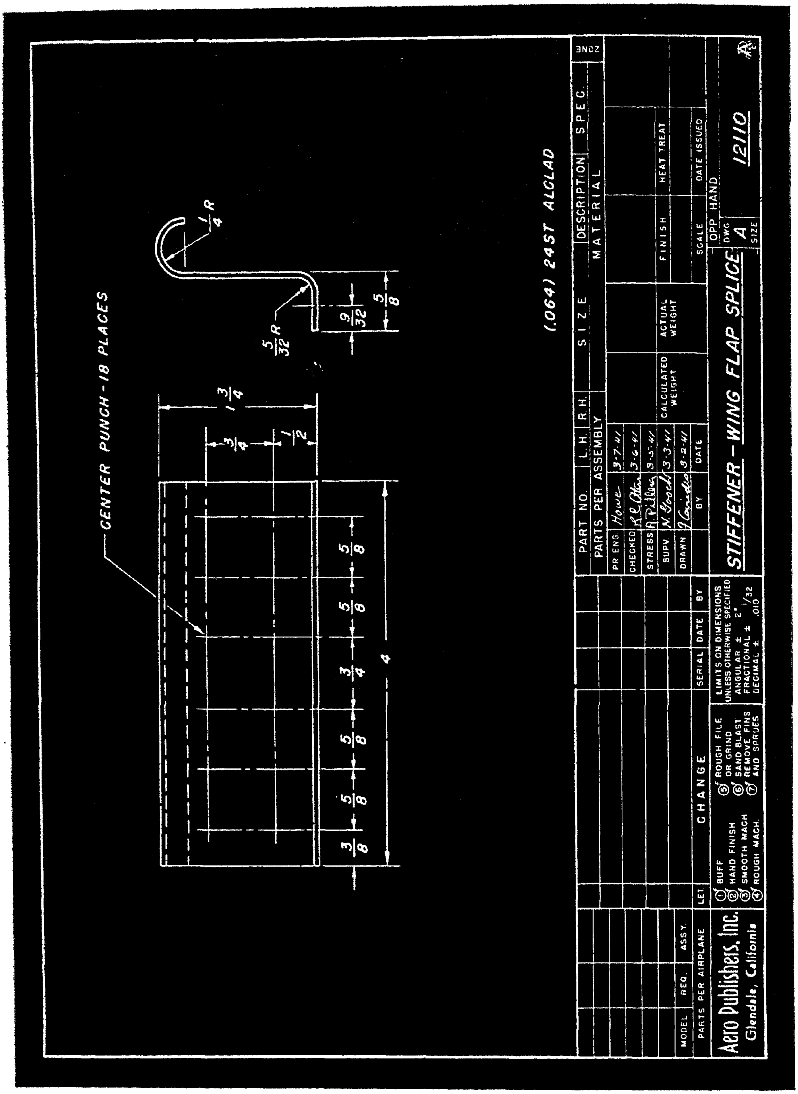


will be computed by subtracting the sum of two thicknesses plus ⅛″ and $\frac{1}{16}$″ radii from the $1\frac{11}{16}$″ dimension. Locate centers of all holes.

Problem No. 12110

Title:

Stiffener—Wing Flap Splice.

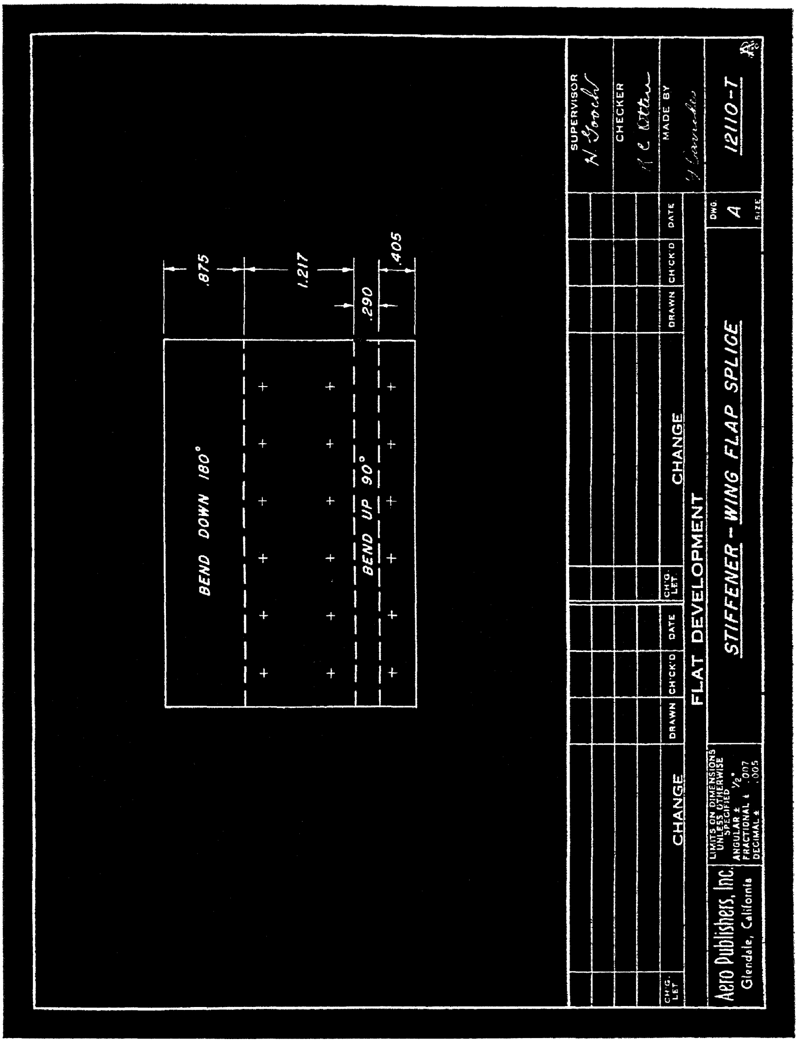


Object:

To develop a template for a part having two bends in opposite directions, one of them being a 90° bend, the second bend 180°.

Procedure:

Subtract the sum of the thickness plus the radius from the ⅝" dimension. Add the bend allowance for the 90° bend using .064



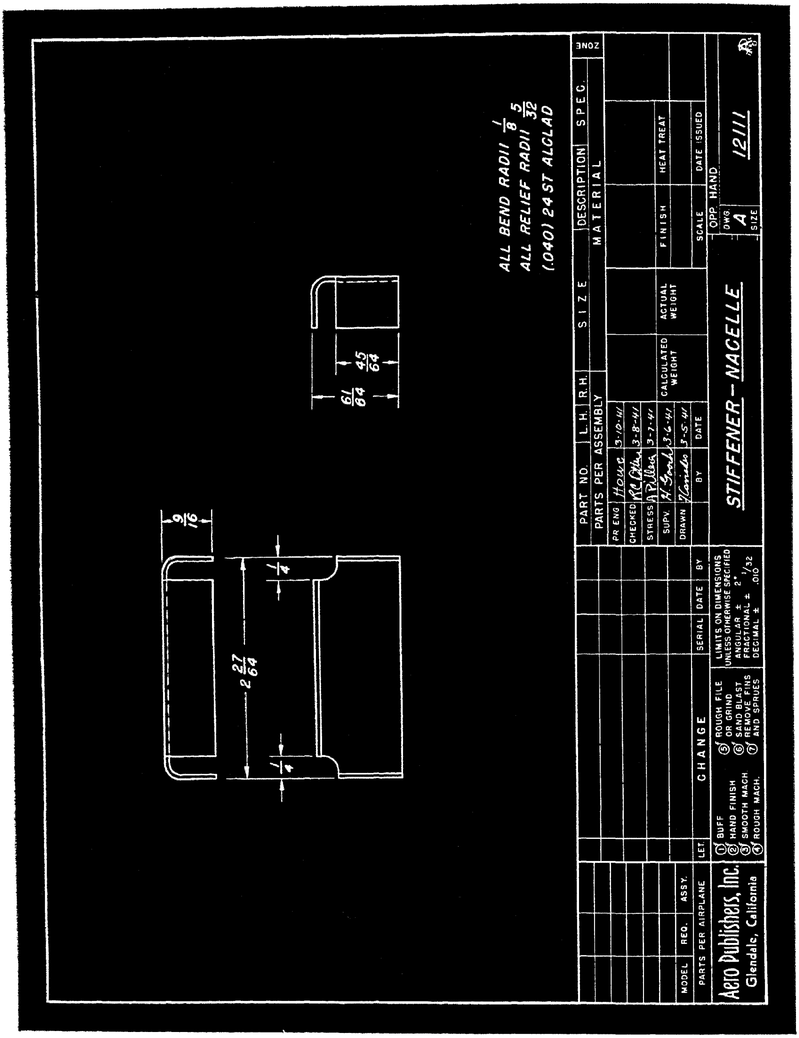
material and $\frac{5}{32}$" radius. Subtract the sum of the two bend radii and two thicknesses of metal from the 1¾" dimension, the remainder from this subtraction is the flat distance between bends.

(Continued on page 249)

Problem No. 12111

Title:

Stiffener—Nacelle.

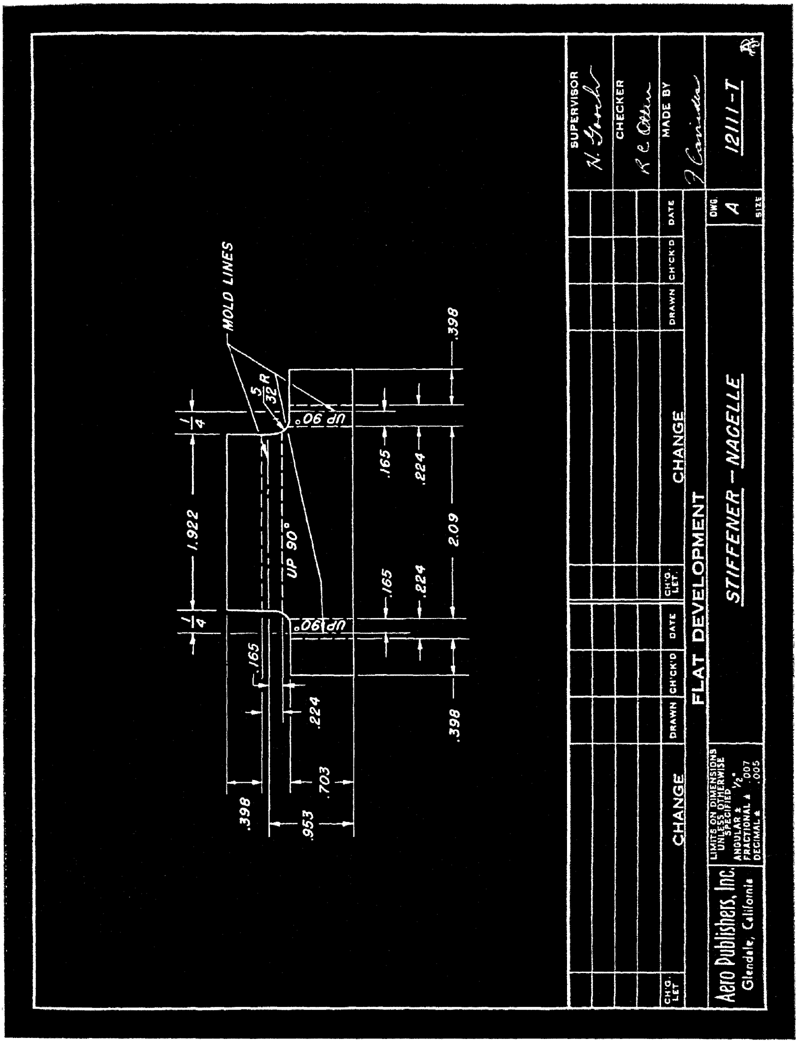


Object:

To develop a template for a part having three 90° bends.

Procedure:

Draw a rectangle $2^{27}/_{64}$" in length and $^{61}/_{64}$" in width. This rectangle now represents the exact outside shape of the lower left

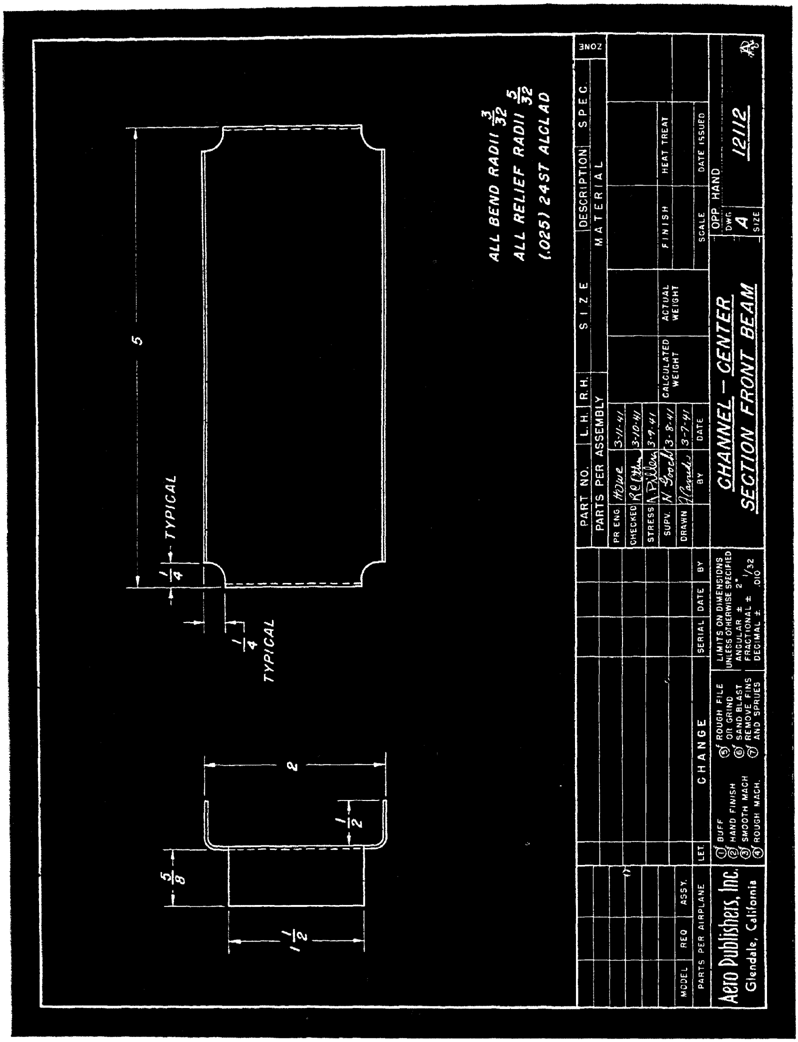


hand view of the drawing. On the three sides which have flanges, draw parallel lines, metal thickness plus bend radius inside of the original lines. These lines represent the beginning of the bend. The

(Continued on page 250)

Problem No. 12112

Title:
Channel—Center Section Front Beam.

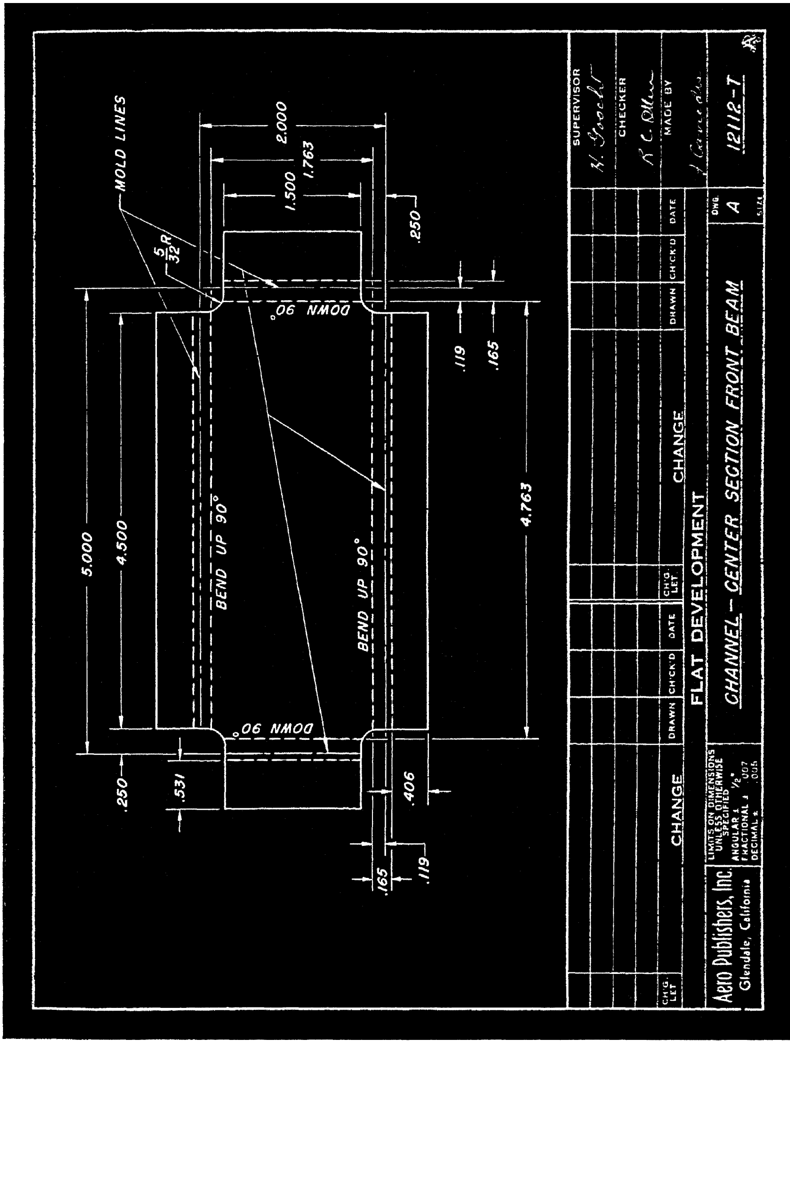


Object:

To develop a template for a part having four 90° bends, two of them bending in one direction, the remaining two in the opposite direction.

Procedure:

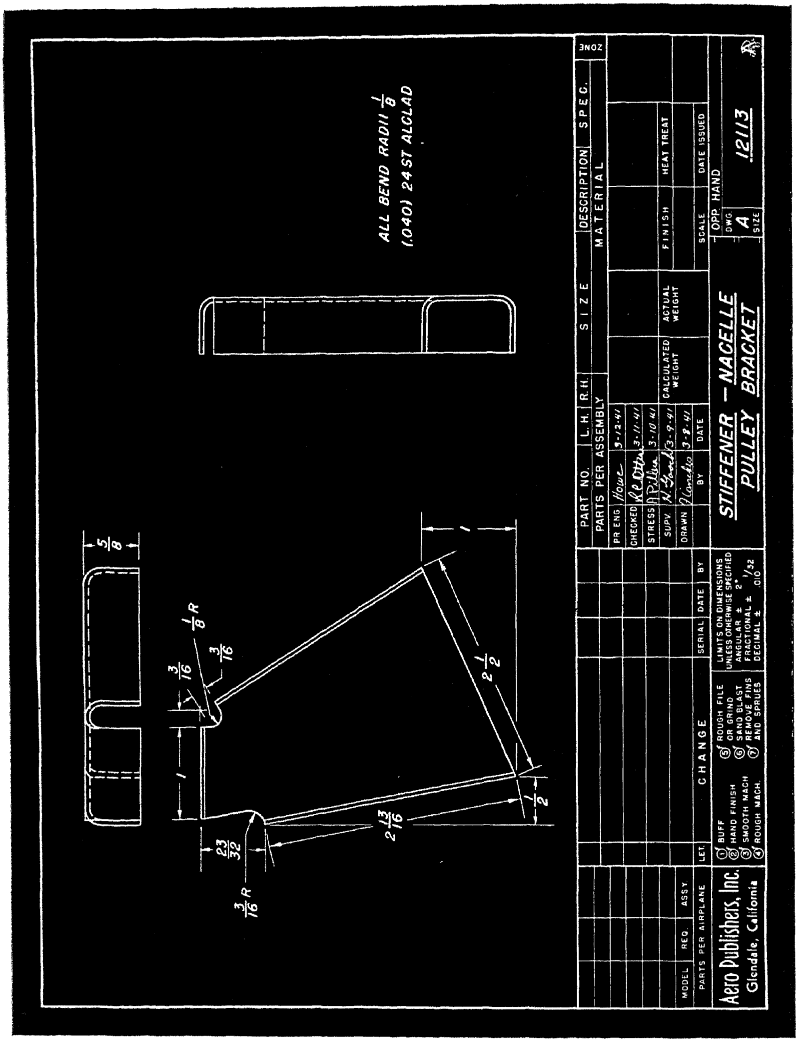
See Problems 12111 and 12108.



Problem No. 12113

Title:

Stiffener—Nacelle Pulley Bracket.

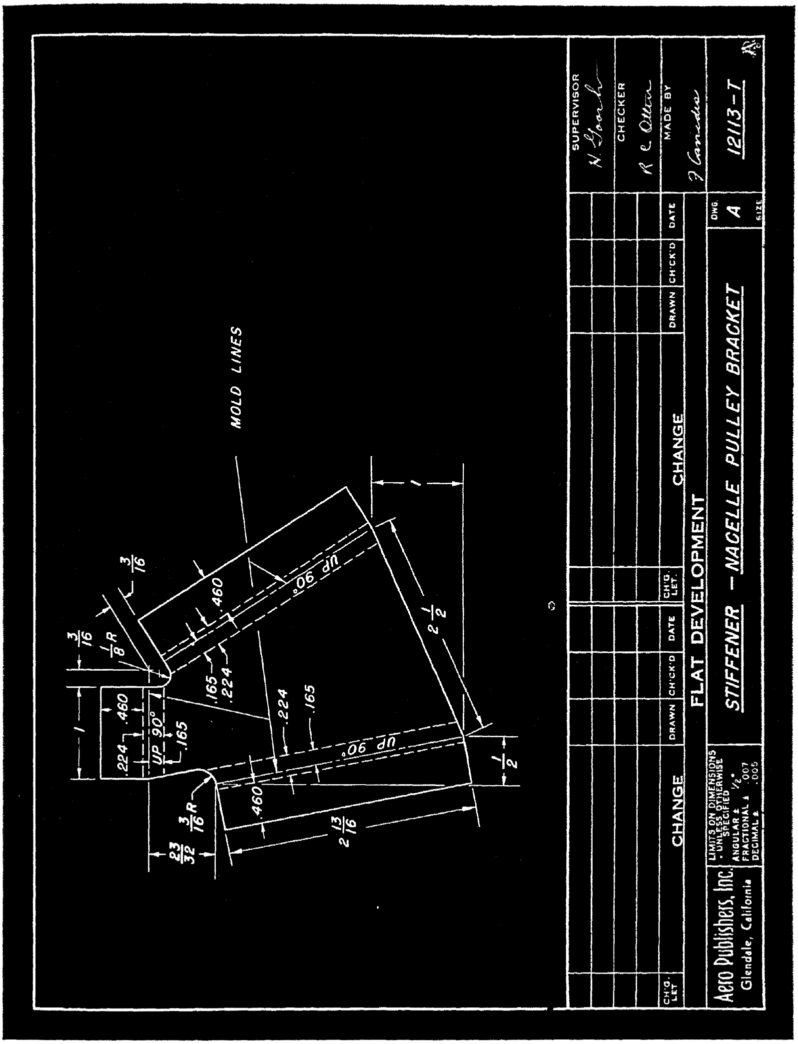


Object:

To develop a template for a part having three bends with none of the sides being parallel to another.

Procedure:

Draw outline of front view of part, thus establishing the three mold lines.

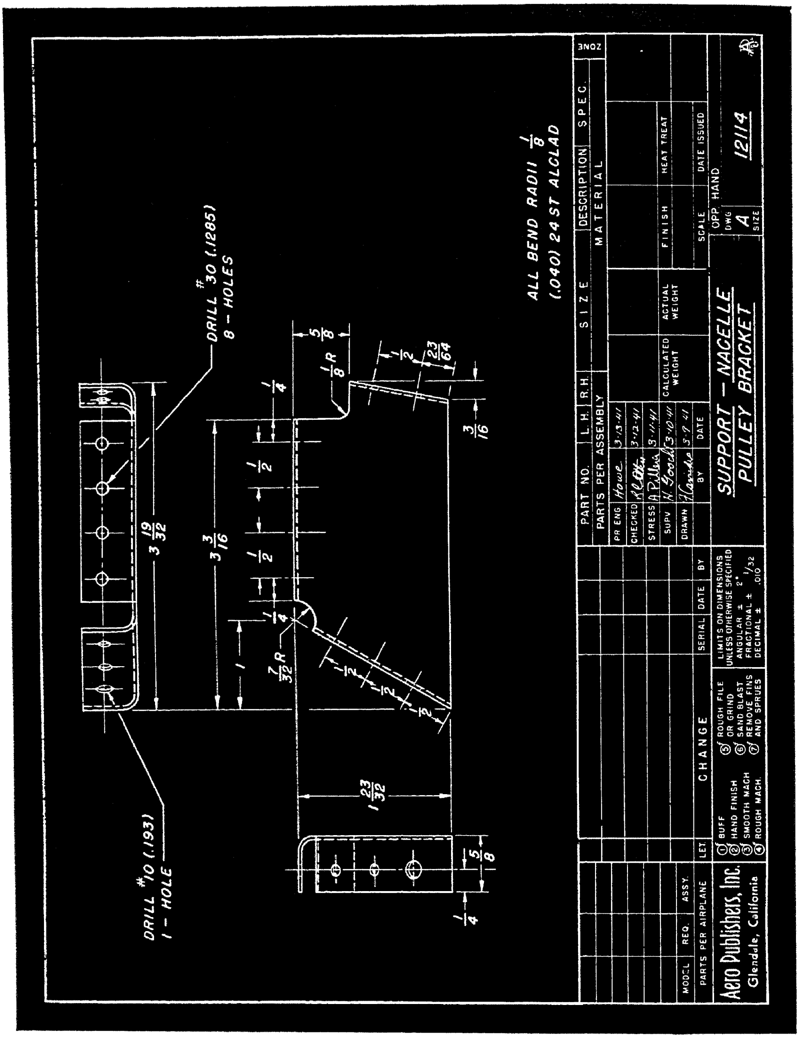


For location of bend lines and flange outlines refer to procedure on problem No. 12111. To complete flat pattern indicate direction of bend.

Problem No. 12114

Title:

Support—Nacelle Pulley Bracket.

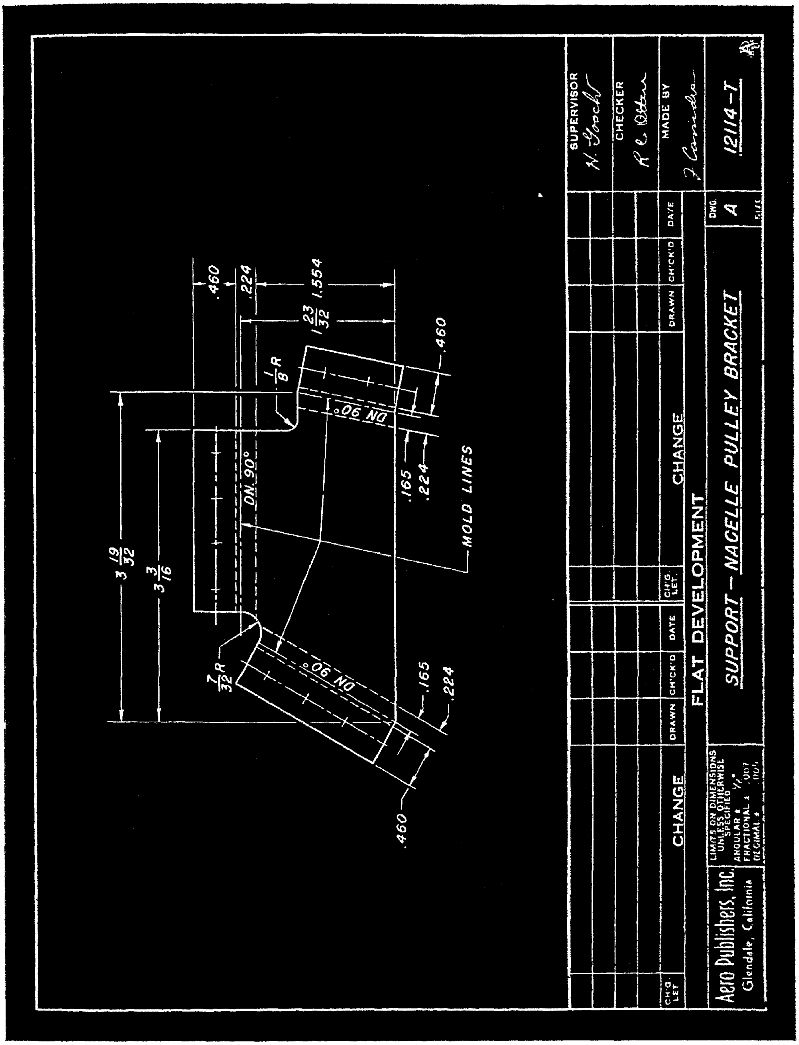


Object:

To develop a flat pattern whose procedure closely parallels that of problem No. 12113.

Procedure:

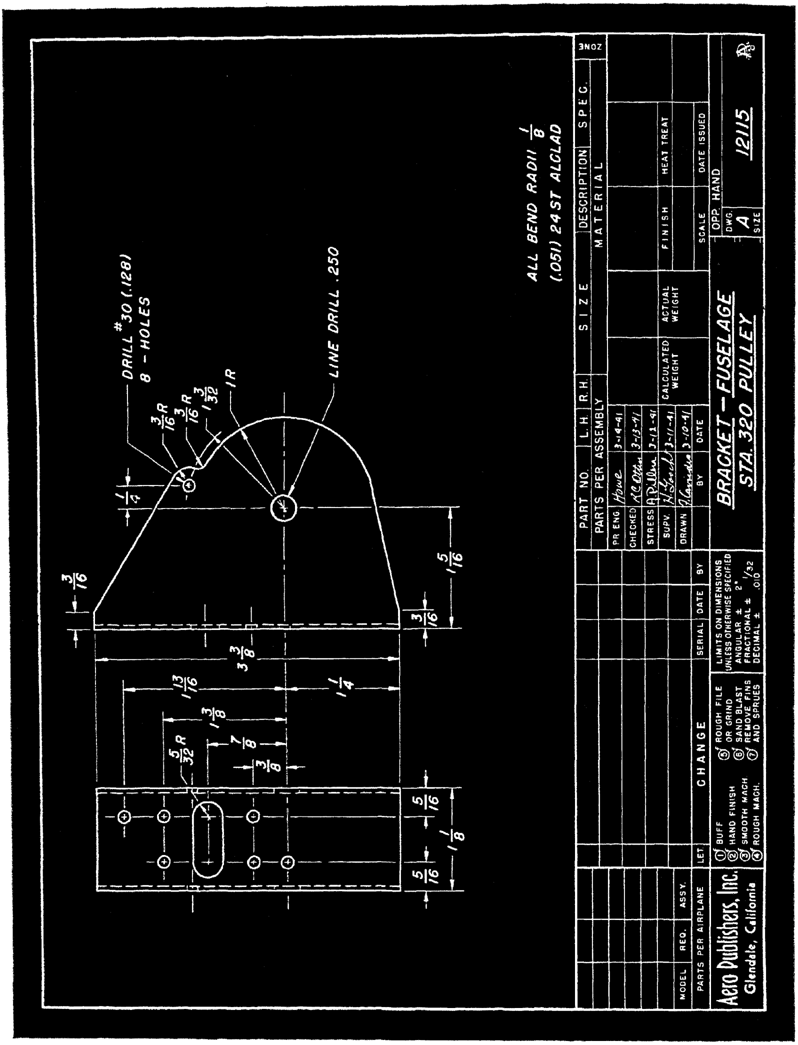
To lay out flat pattern, follow method used for problem No. 12113. Locate all holes.



Problem No. 12115

Title:

Bracket—Fuselage—Sta. 320. Pulley.

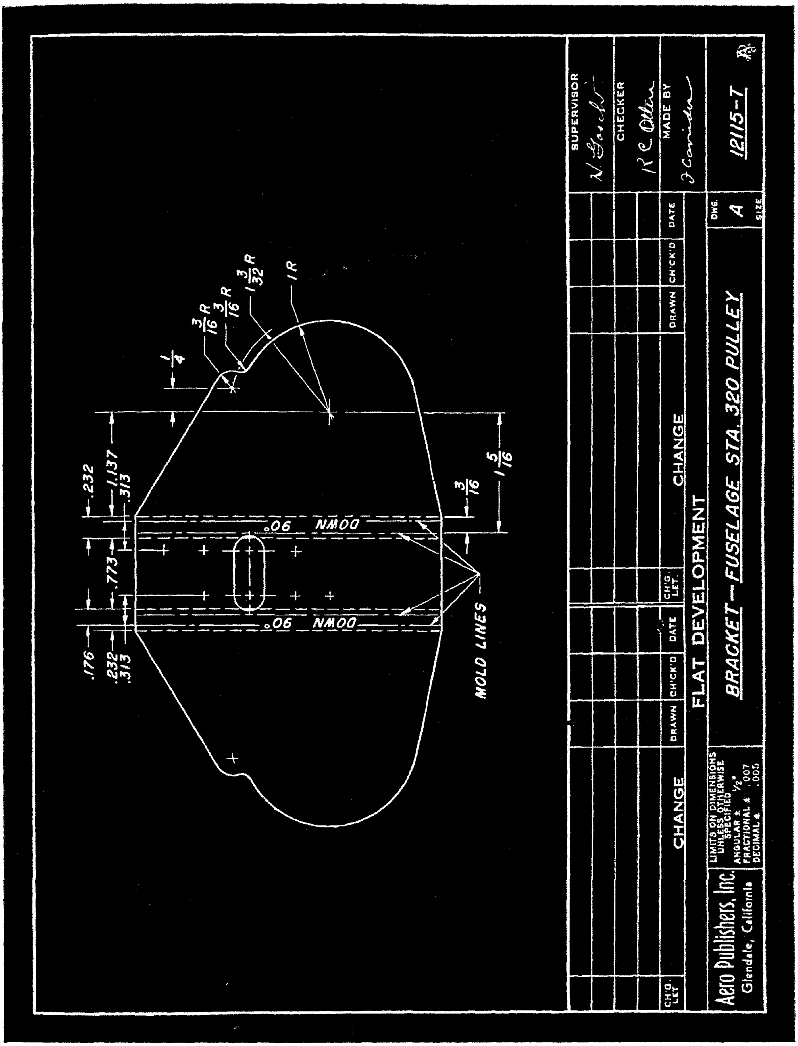


Object:

To develop a pulley bracket whose two sides are identical.

Procedure:

In order to take full advantage of the possibility of saving time, the development of this pulley bracket should be started by draw-



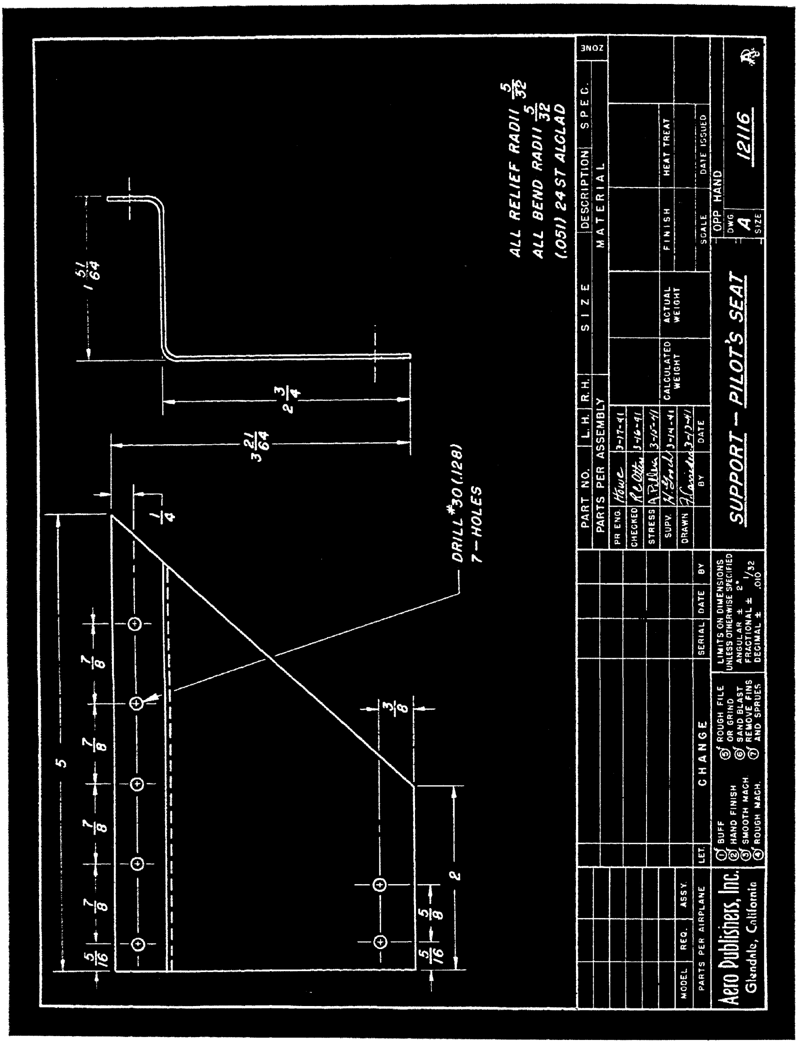
ing a rectangle 3⅜″ by 1⅛″. Let the two 3⅜″ sides represent the mold lines from which the horizontal dimensions are given for locating the cutout and six holes. Bend lines are located as in previous problems.

(Continued on page 250)

Problem No. 12116

Title:

Support—Pilot's Seat.

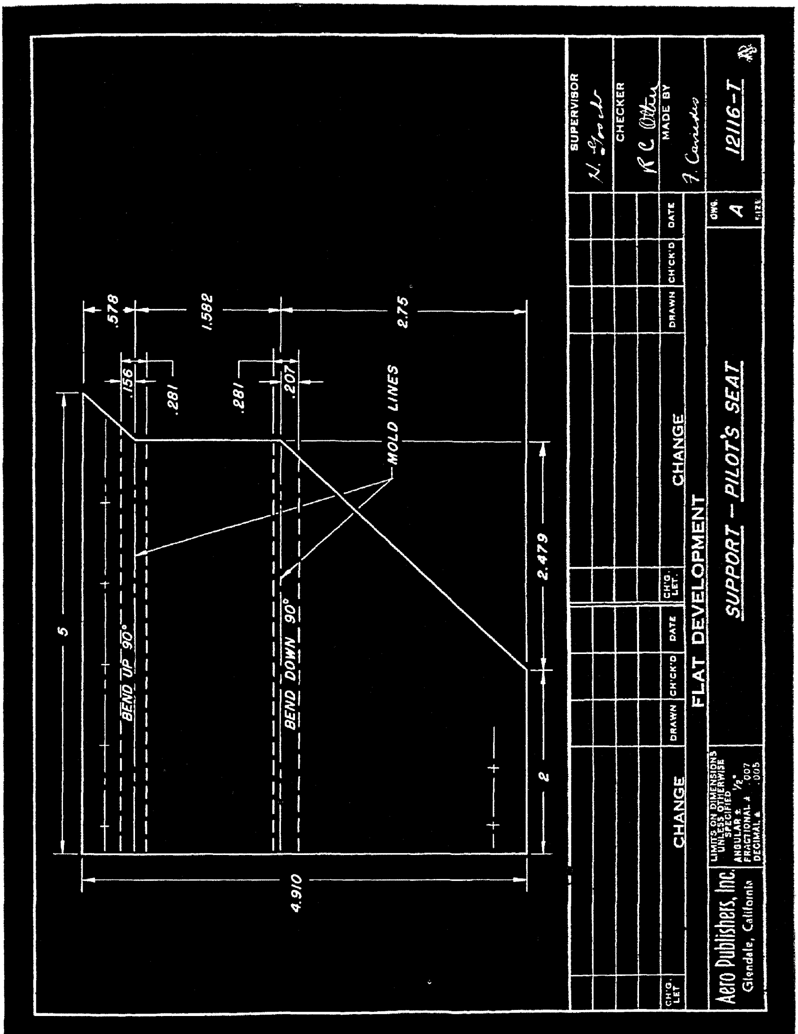


Object:

To develop a flat pattern for a part having two 90° bends and a diagonal end cut.

Procedure:

Draw a horizontal line and erect two perpendicular lines 5 inches apart which determine the maximum horizontal width of



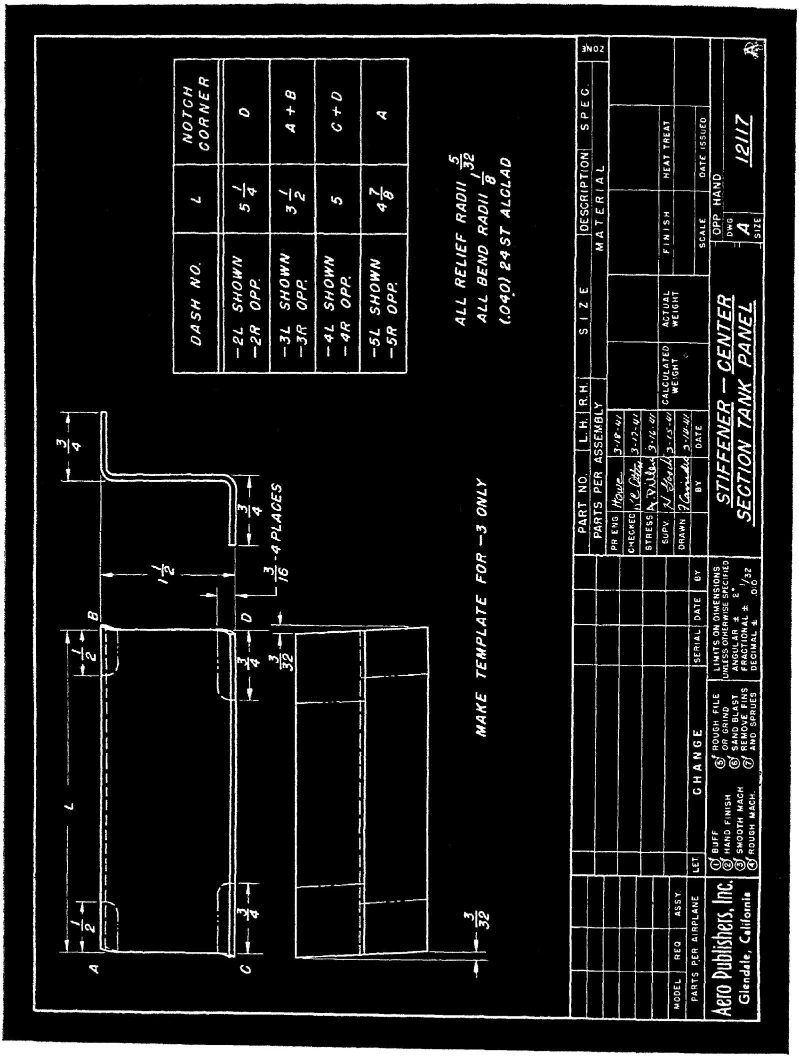
the flat pattern. On horizontal line locate beginning of a diagonal end cut. Draw bend lines and upper end of flat pattern. Locate the two mold lines which are intersected by the diagonal cut in the

(Continued on page 250)

Problem No. 12117

Title:

Stiffener—Center Section—Tank Panel.

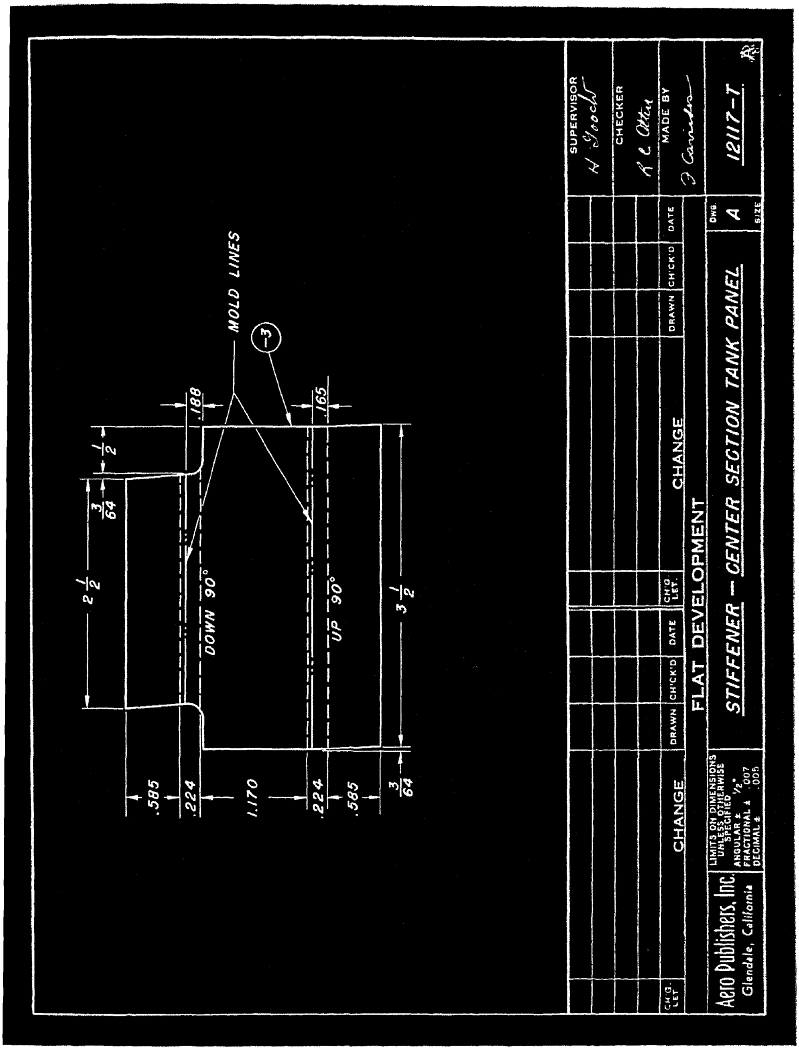


Object:

To become acquainted with tabulated information and to develope a template from this information.

Procedure:

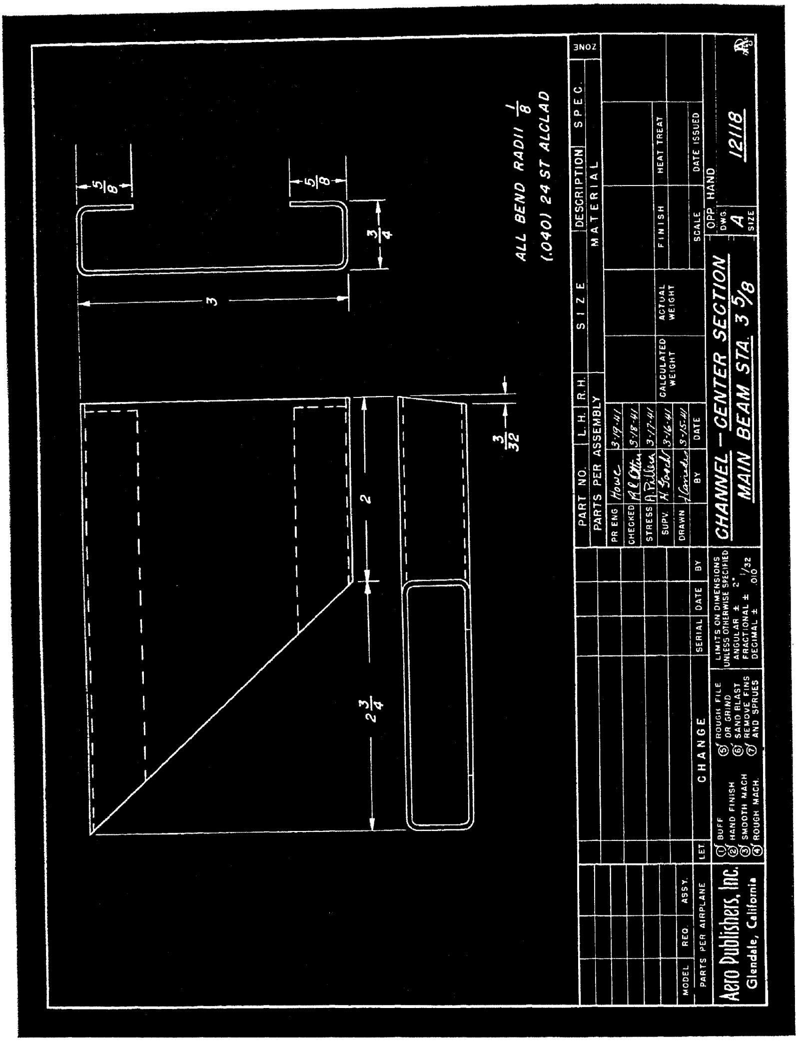
Similar to previous problems.



Problem No. 12118

Title:

Channel—Center Section Main Beam Sta. 3⅝.

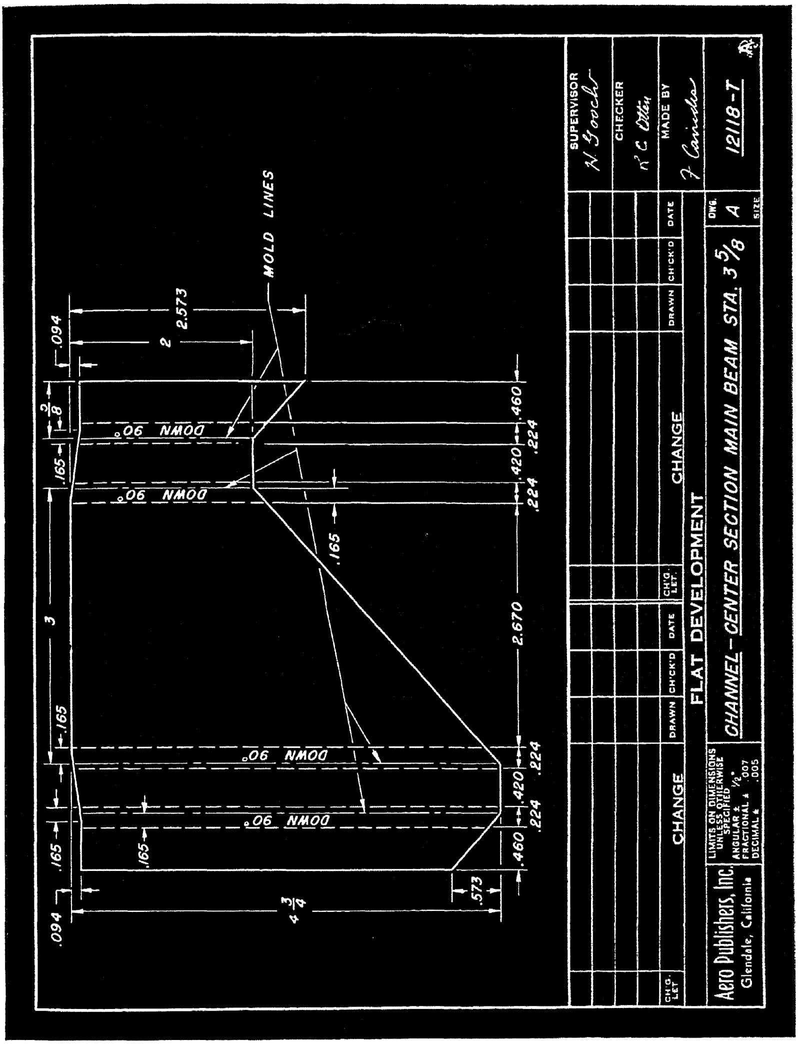


Object:

To develop a template for a channel which has two diagonal cuts.

Procedure:

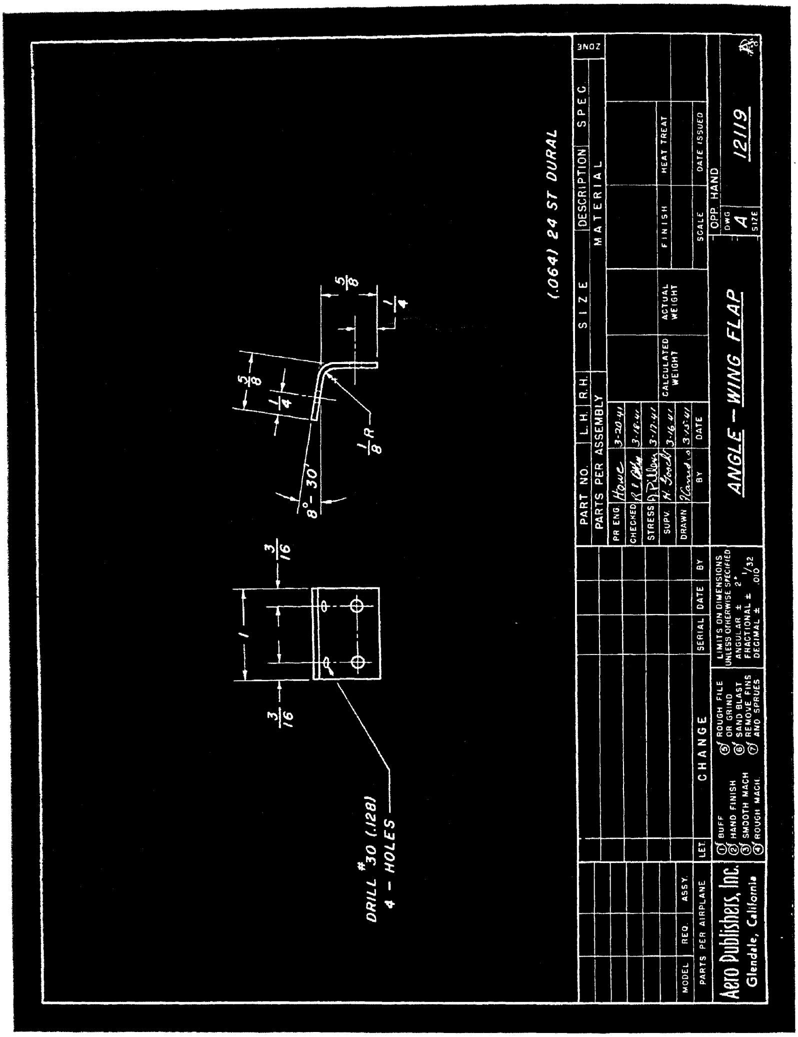
Disregard the diagonal cuts until after the complete development blank has been laid out. See Chapter 6 for information on diagonal cuts.



Problem No. 12119

Title:

Angle—Wing Flap.

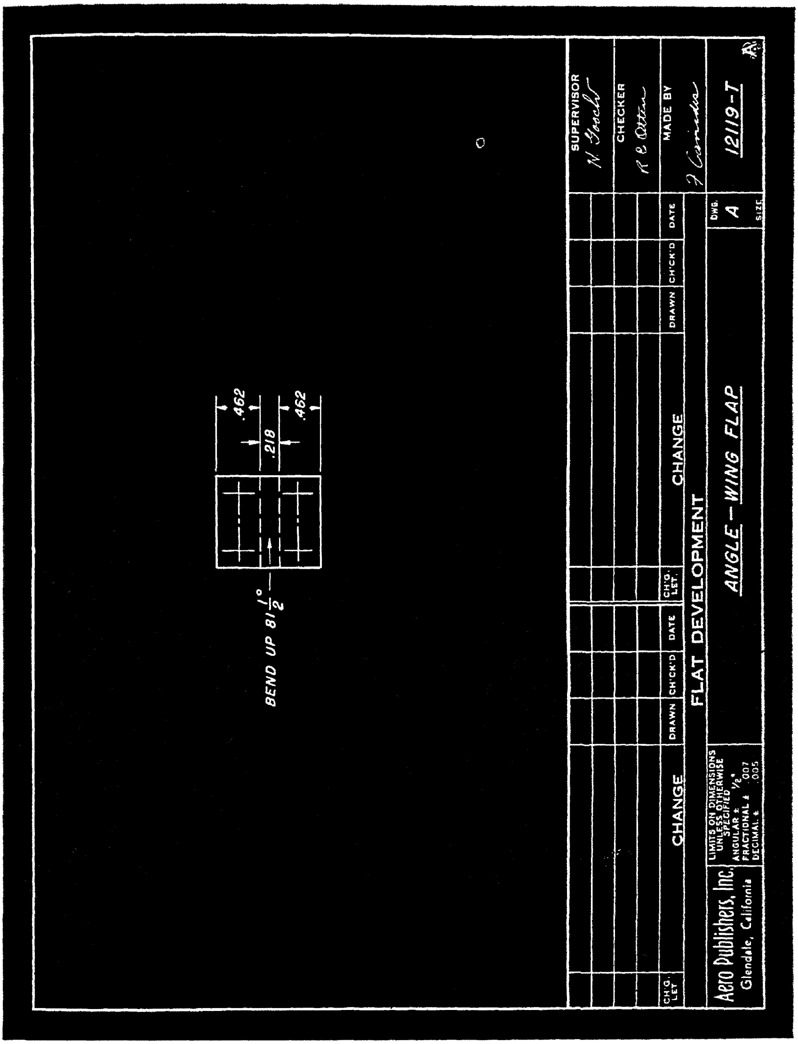


Object:

To develop a template for a part bent less than 90°.

Procedure:

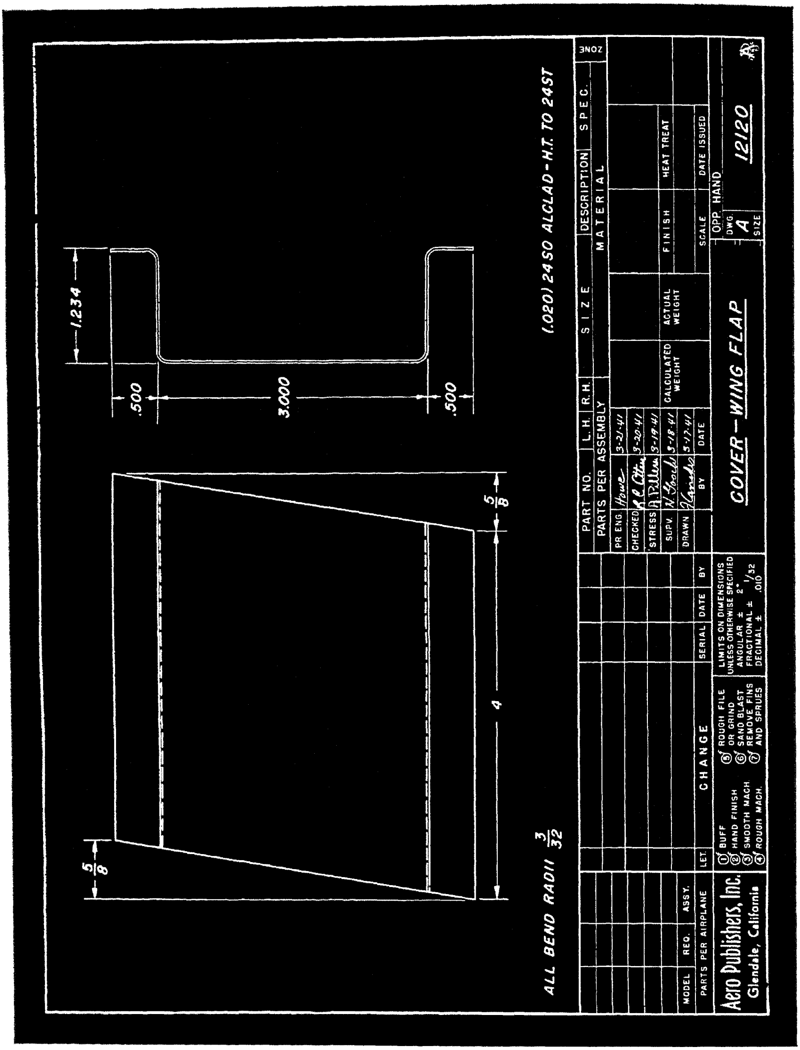
Refer to discussion on bends of more or less than 90° in Chapter 6.



Problem No. 12120

Title:

Cover—Wing Flap.

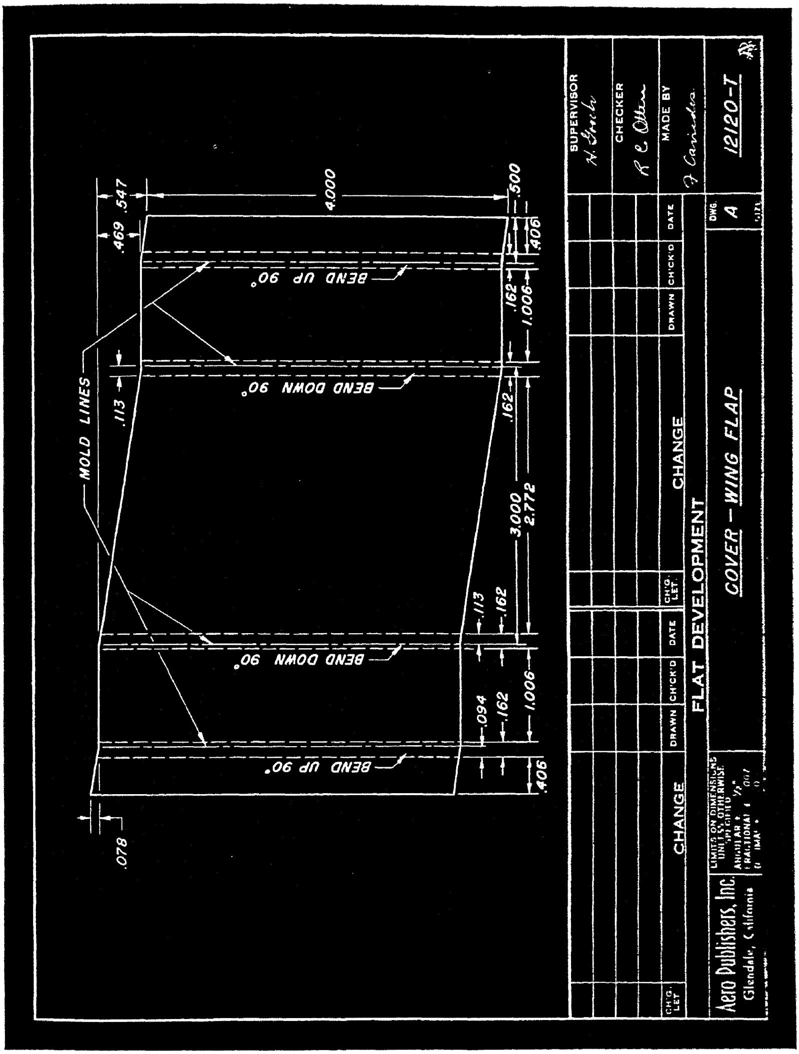


Object:

To develop a template for a part having four 90° bends. Also, to develop the end cut on the template so that the finished formed part will have a slanted cut as per print.

Procedure:

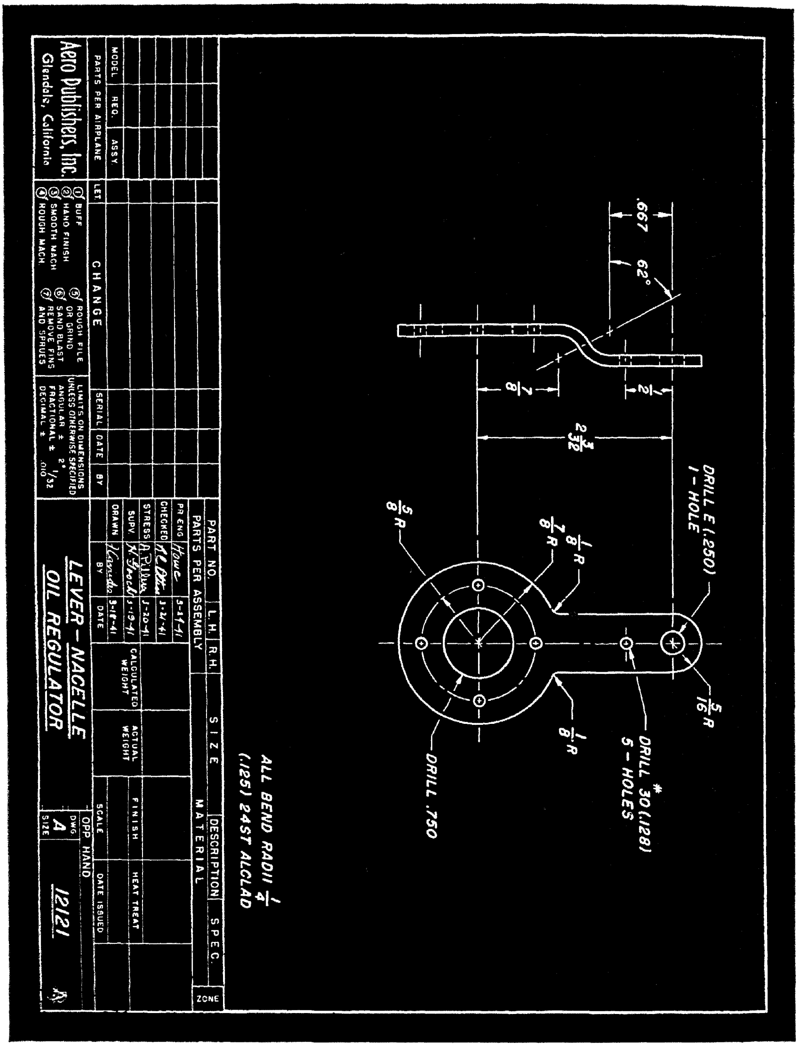
The entire development of this cover shall be put down with no attempt to make end cuts until all bend lines and mold lines



have been put into their proper relationship to each other. For proper procedure in developing end cuts, refer to the sketch on use of mold lines in developing a diagonal cut. Chapter 6.

Problem No. 12121

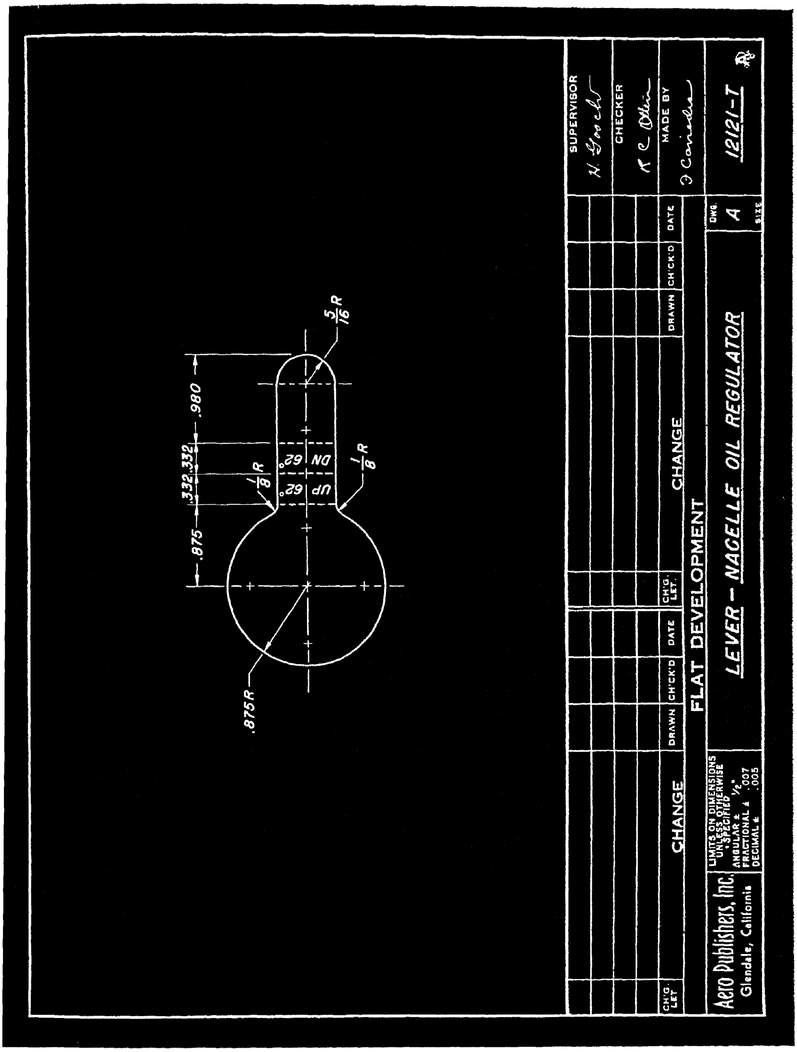
Title:
Lever—Nacelle Oil Regulator.



Object:
Develop flat pattern for Control Lever.

Procedure:

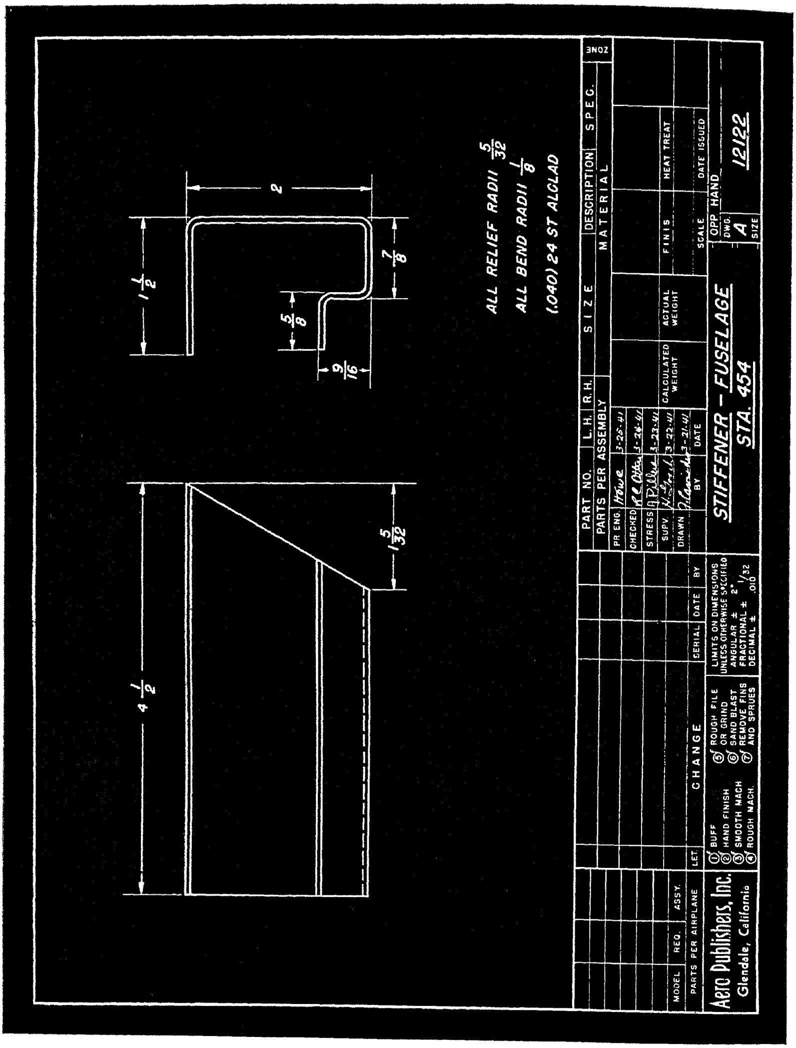
Construction is similar to problem No. 12103 except for bend allowance.



Problem No. 12122

Title:

Stiffener—Fuselage—Sta. 454.

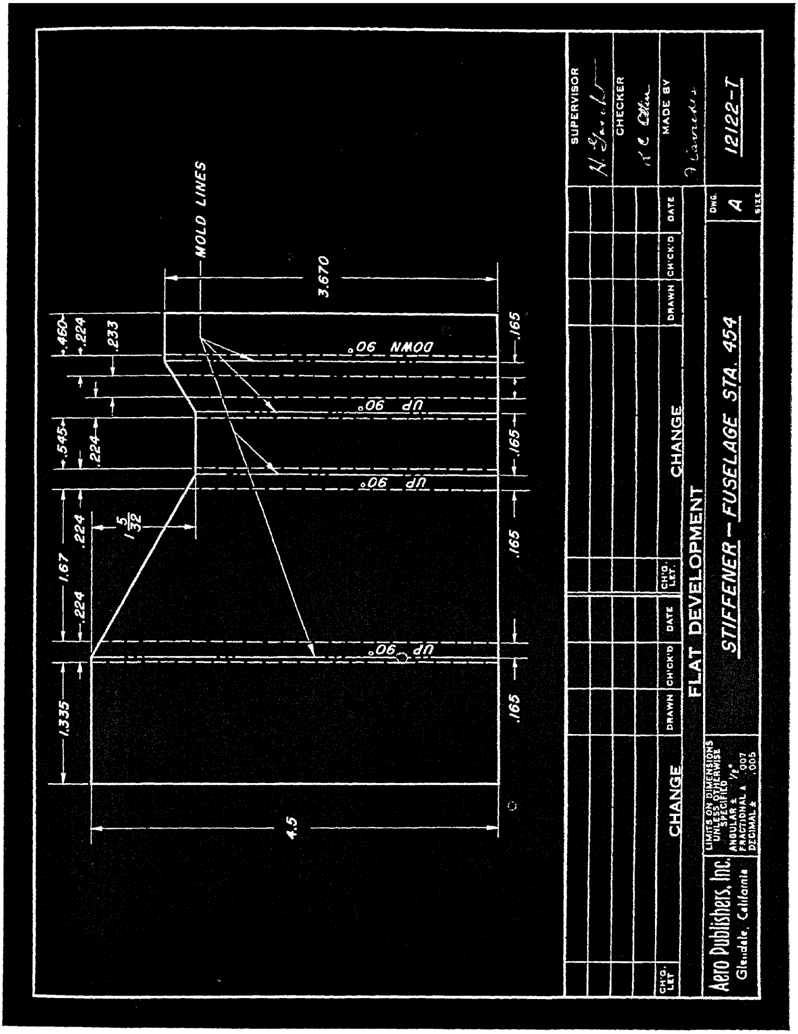


Object:

To develop a flat template for a part having four bends and a diagonal cut.

Procedure:

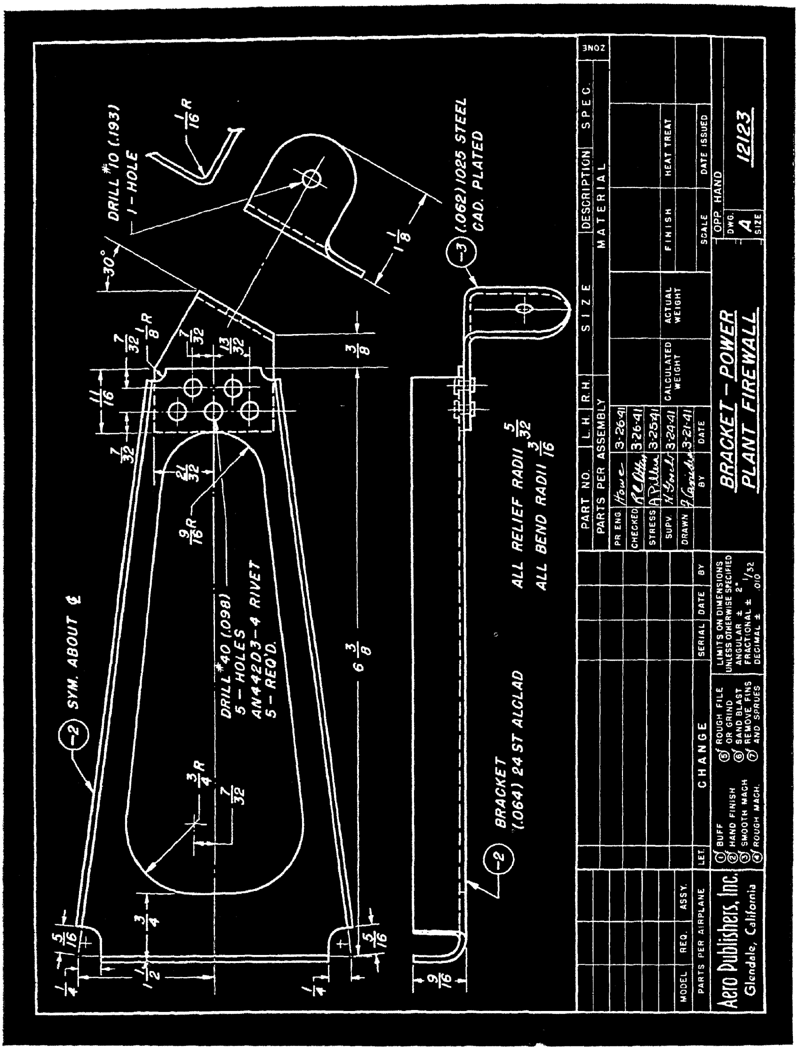
Similar to that which is outlined in problem No. 12120.



Problem No. 12123

Title:

Bracket—Power Plant—Fire Wall.

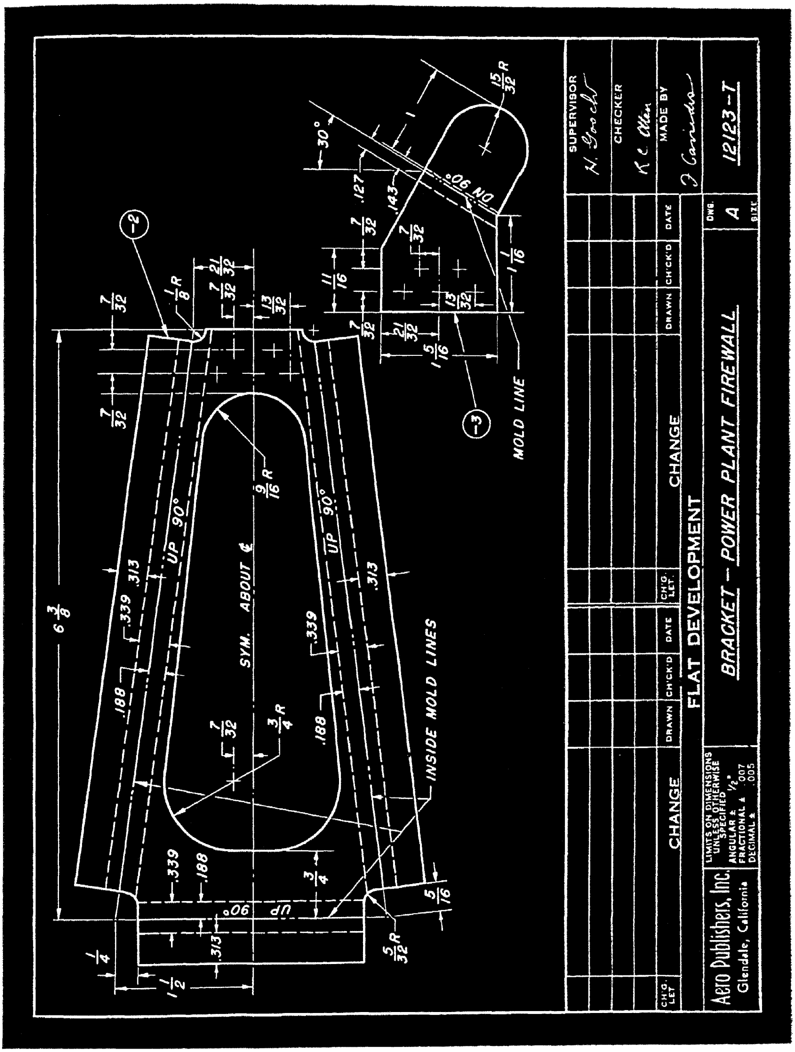


Object:

Develop flat pattern for -2 and -3.

Procedure:

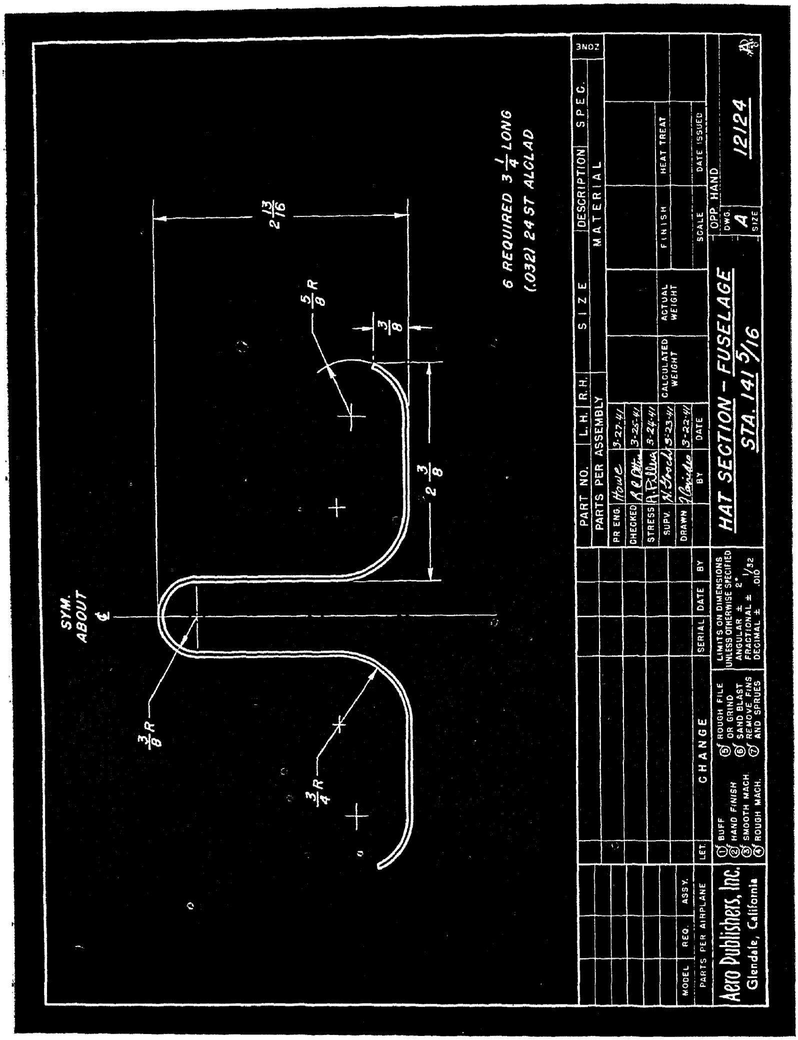
Proceed as with previous problems.



Problem No. 12124

Title:

Hat Section—Fuselage, Sta. 141 $\frac{5}{16}$.

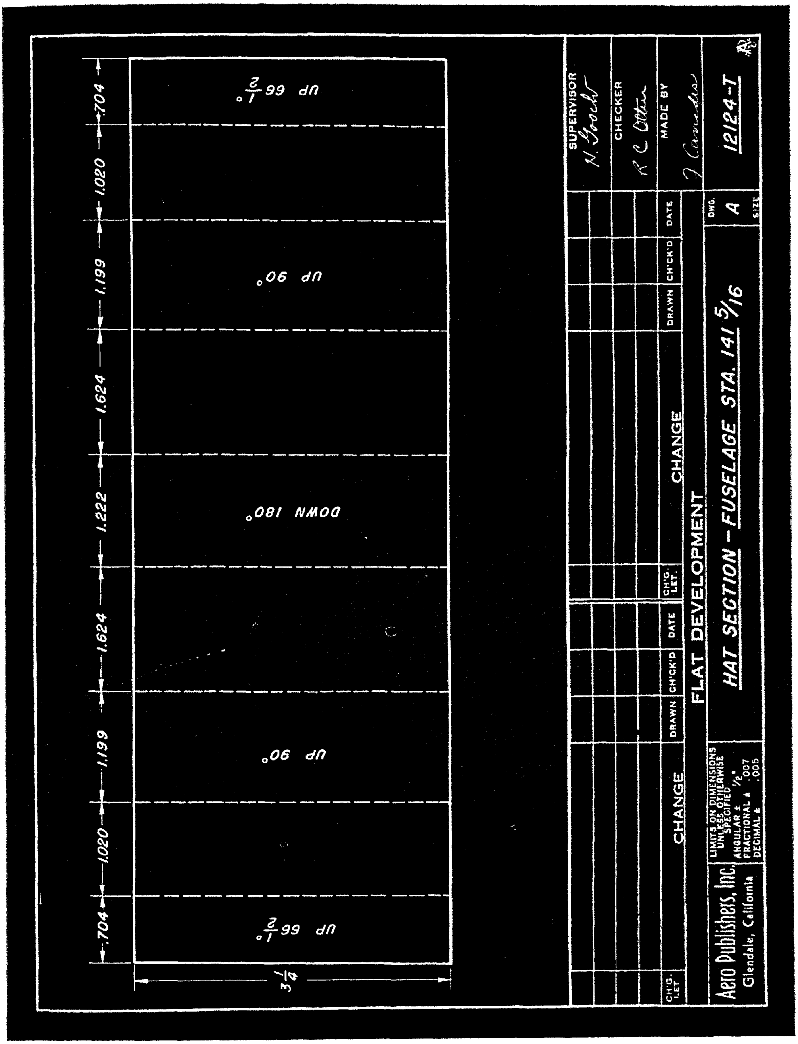


Object:

To develop a flat template for a part which is so dimensioned as to require calculations in order to determine the required degree of bends.

Procedure:

A right triangle is formed by the $5/8$ radius and $3/8$ dimension. Solve for α and the side opposite α. See sketch on page 250.



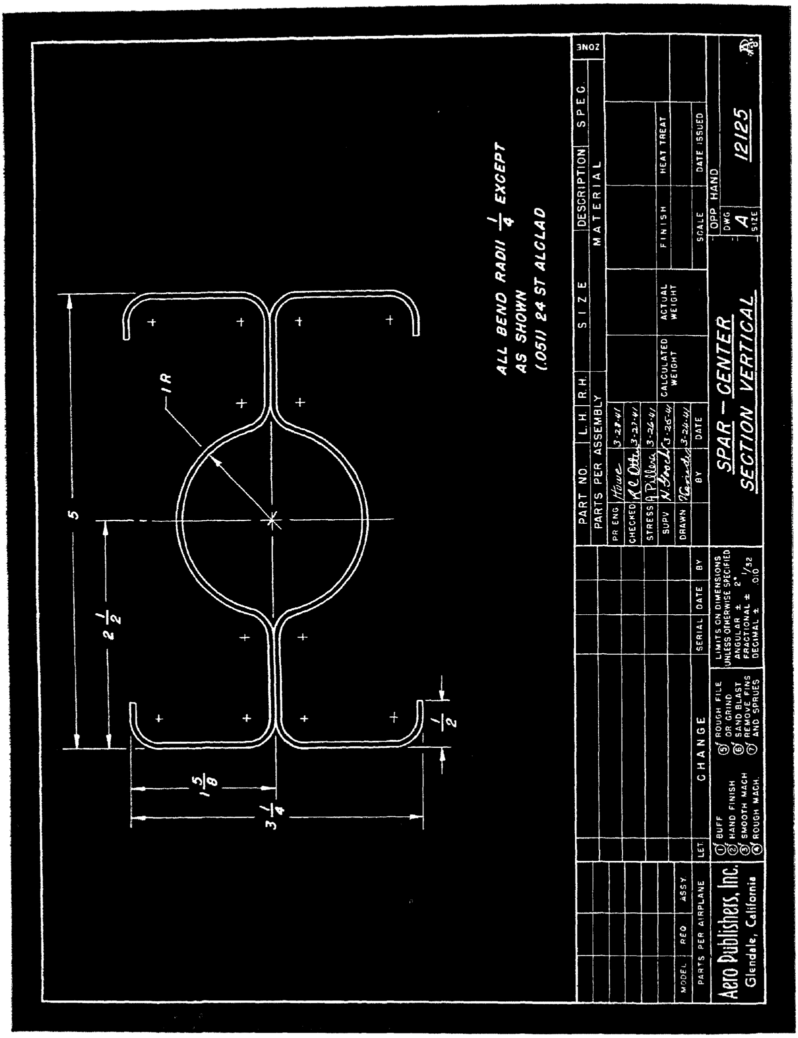
Proceed with the customary method of finding bend allowance. Flat area between $5/8$ radius and $3/4$ radius can be determined by

(Continued on page 250)

Problem No. 12125

Title:

Spar—Center Section Vertical.

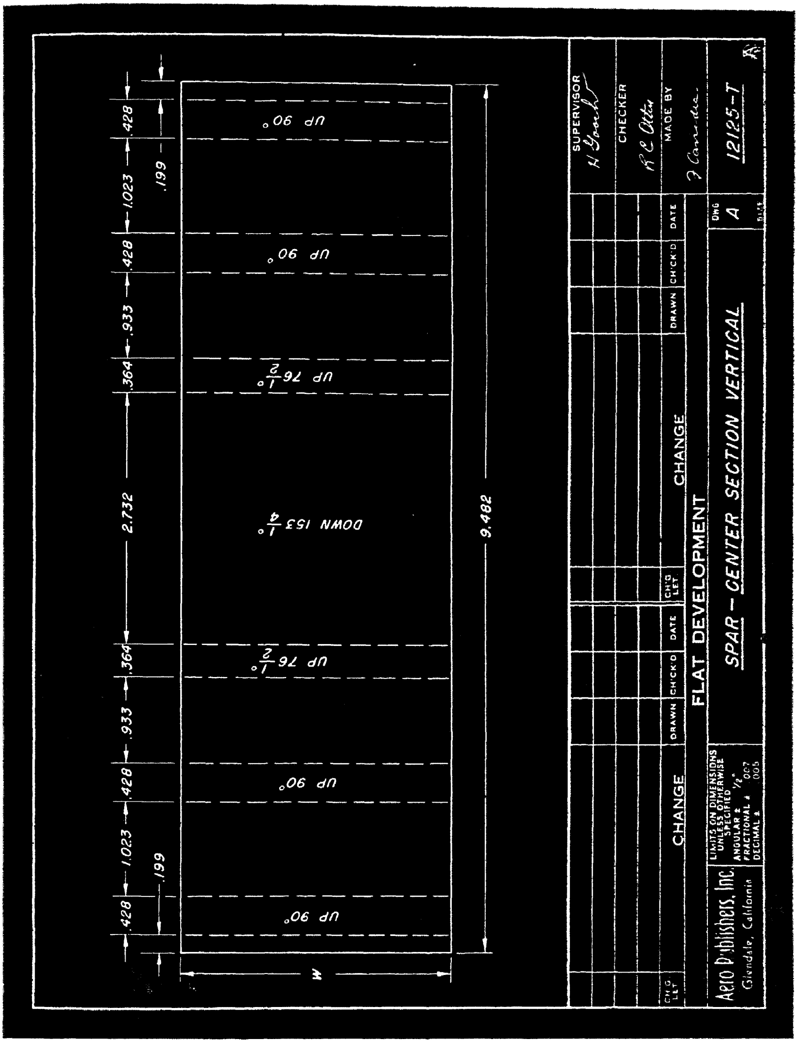


Object:

To develop a flat template for a part which is completely dimensioned but requires mathematical calculations to determine bend angles and flat portions.

Procedure:

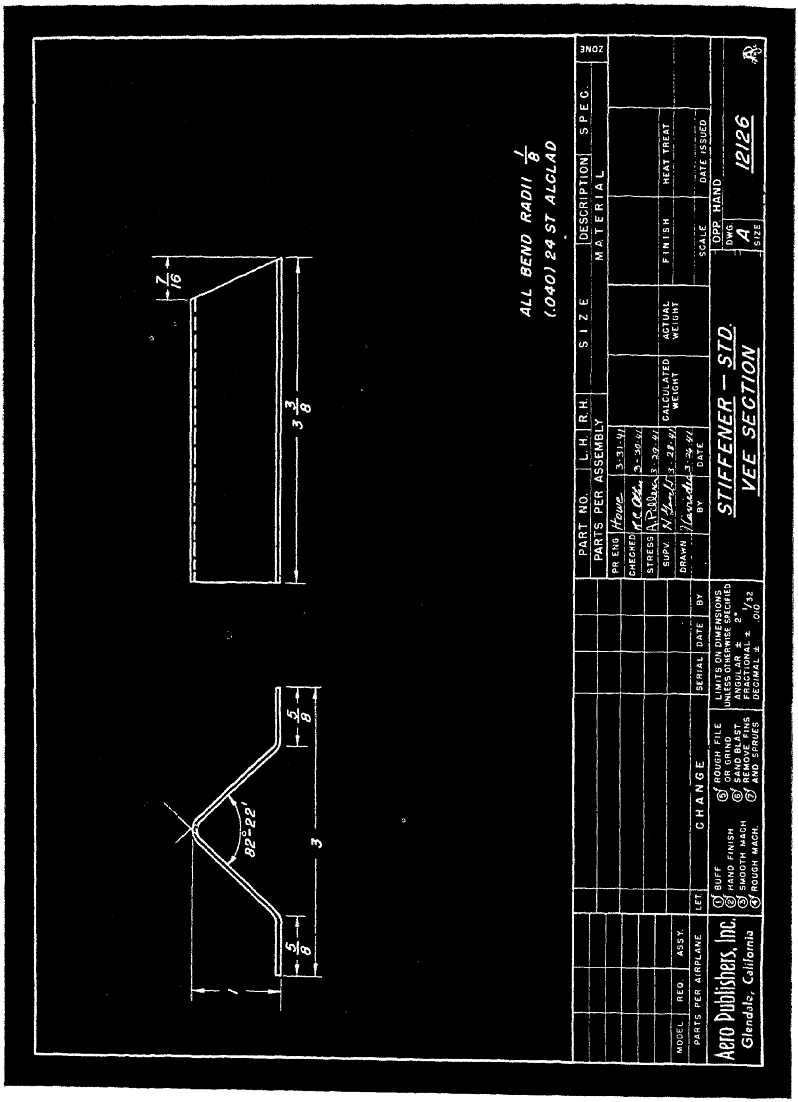
Similar to problem No. 12124.



Problem No. 12126

Title:

Stiffener—Std. Vee Section.

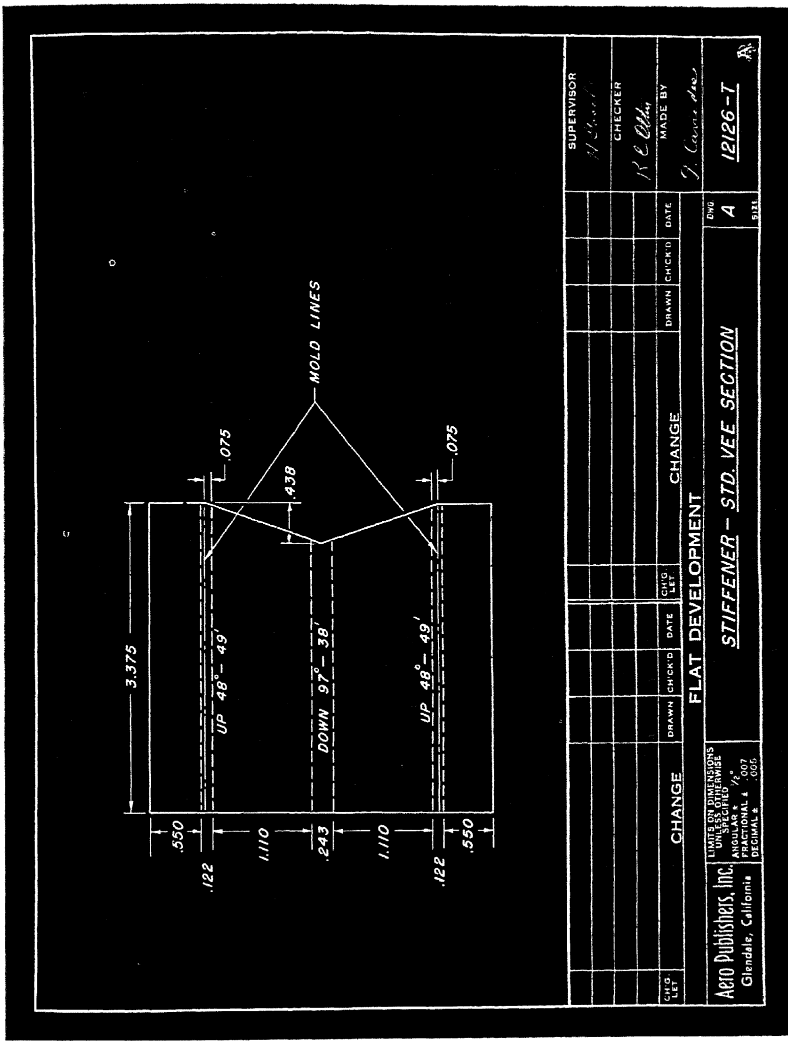


Object:

To develop a template for Vee section stiffener having a diagonal cut as shown in the side view.

Procedure:

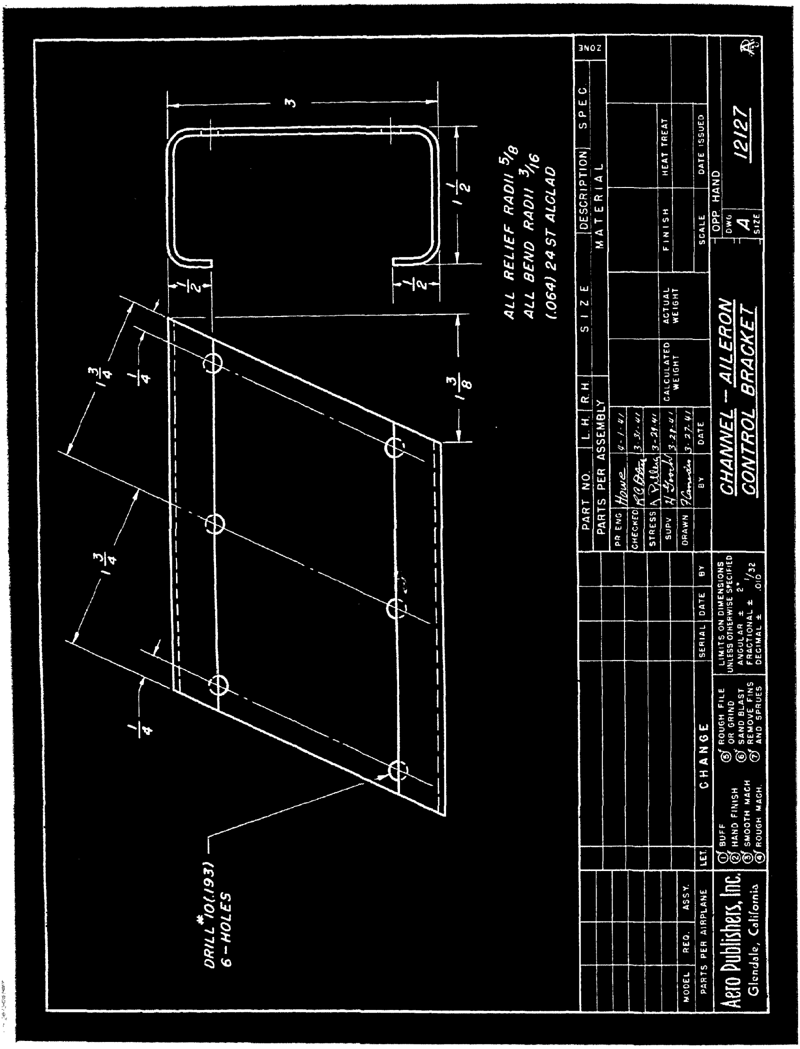
The procedure for development and the method of determin-



ing the angular cut in the developed template has been outlined in Chapter 6.

Problem No. 12127

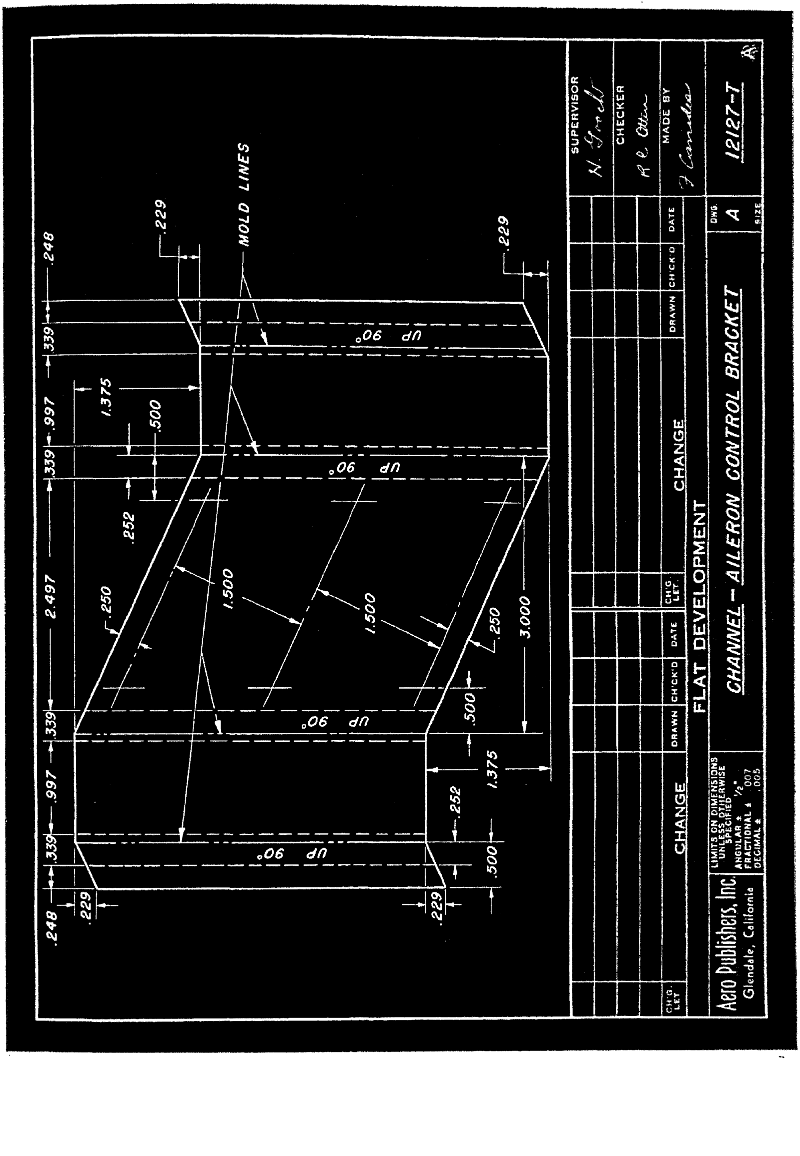
Title:
Channel—Aileron Control Bracket.



Object:
A review of use of mold lines in diagonal cut development.

Procedure:

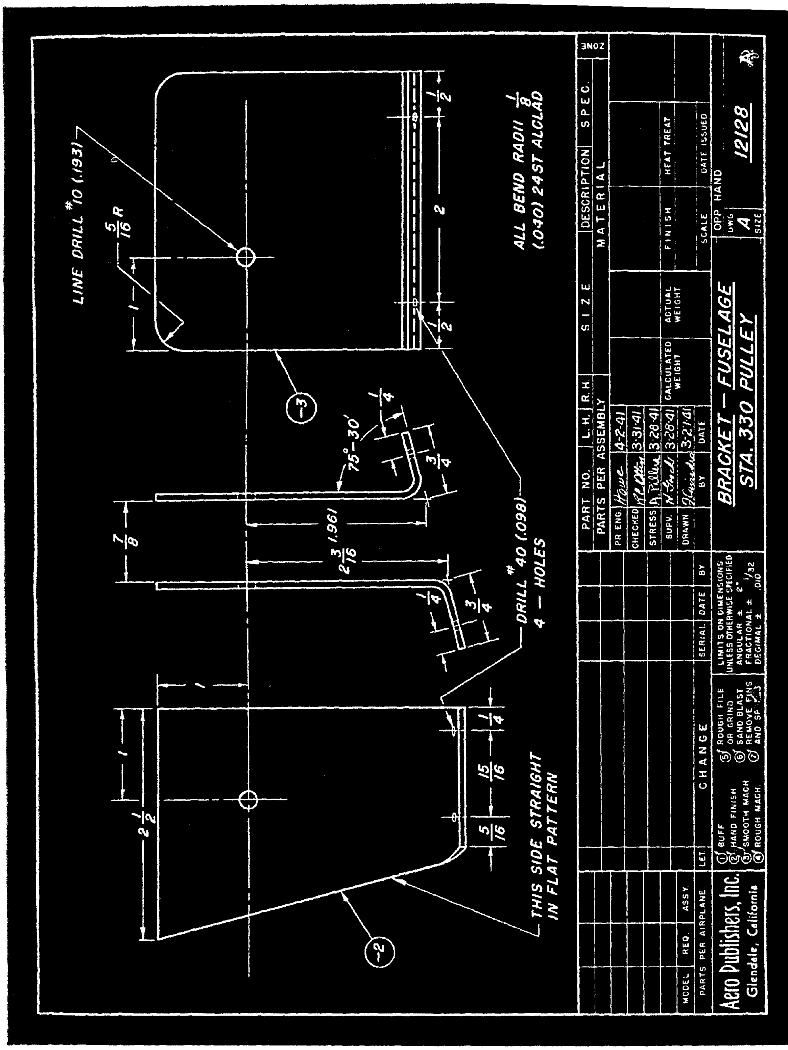
Similar to previous problems of this type.



Problem No. 12128

Title:

Bracket—Fuselage Sta. 330 Pulley.

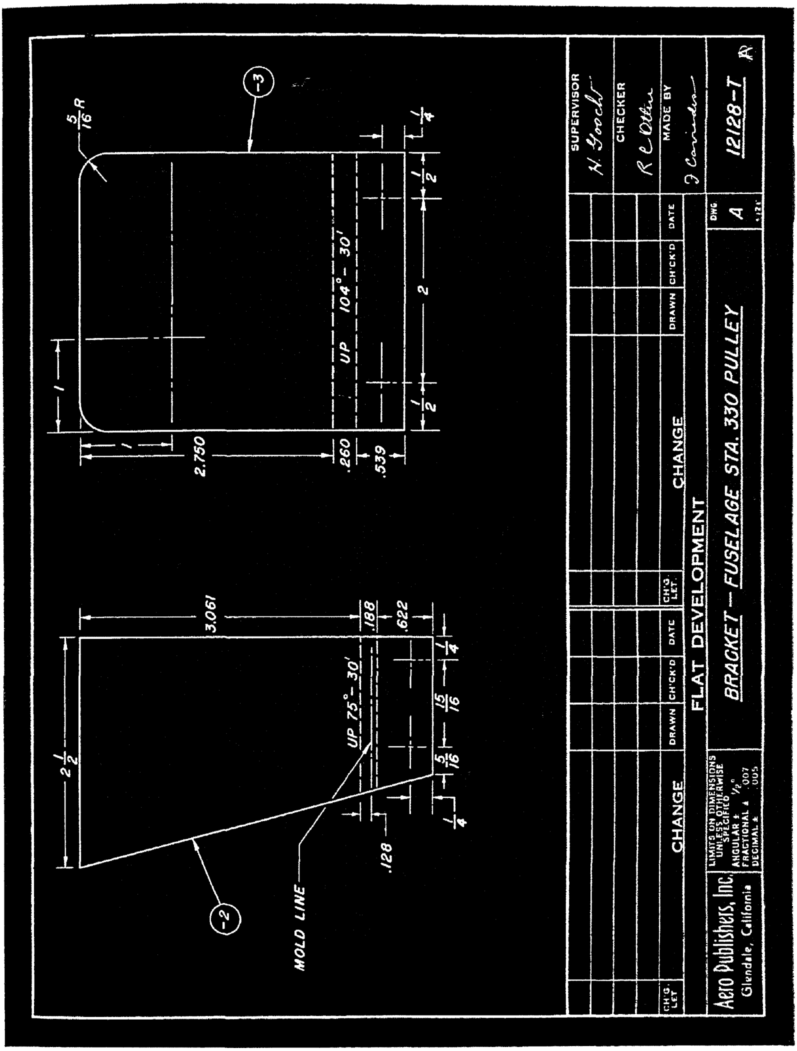


Object:

Develop flat patterns for -2 and -3.

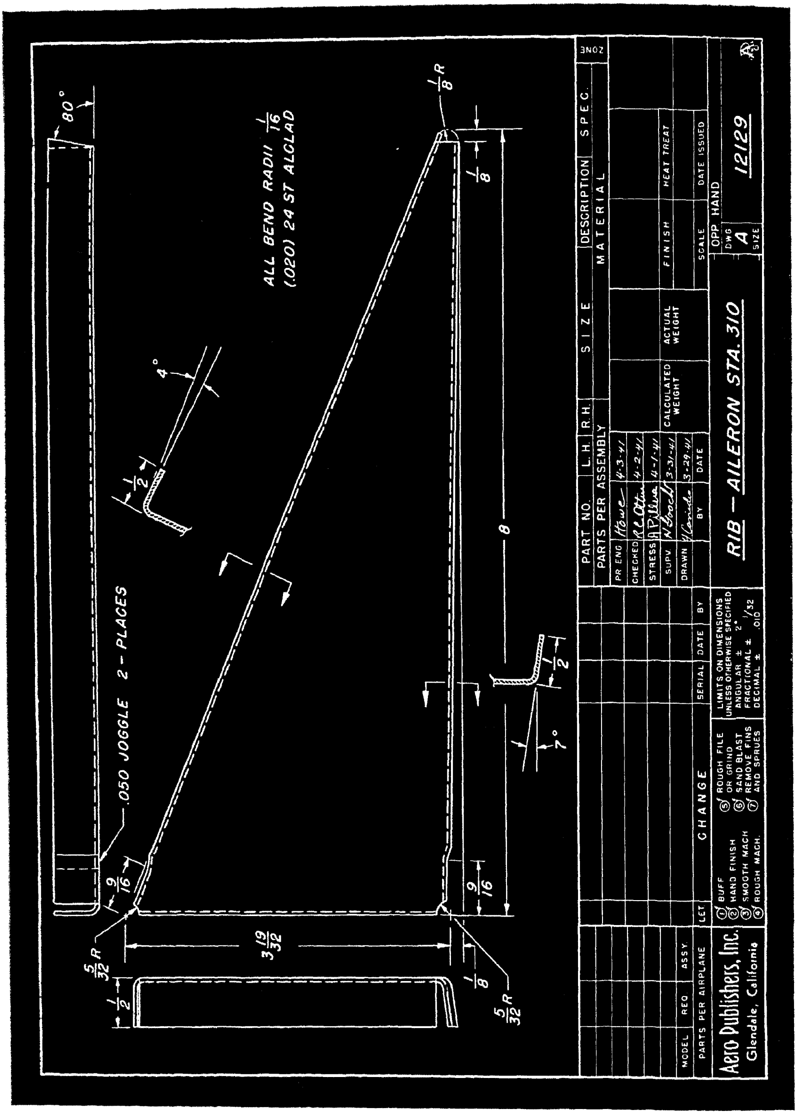
Procedure:

Diagonal cut on -2 will be a straight line completely across flat development. See note at -2 (this side straight in flat pattern).



Problem No. 12129

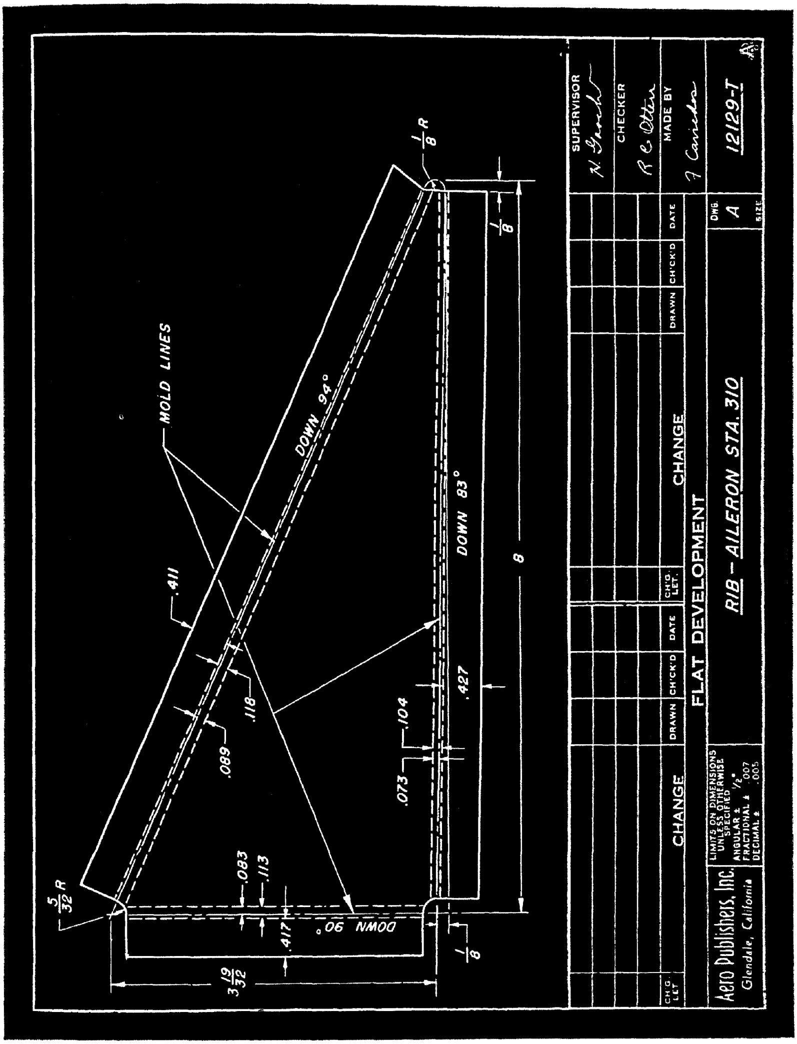
Title:
Rib—Aileron Sta. 310.



Object:
Develop flat pattern for rib.

Procedure:

Lay out the outline of the rib mold lines from the base reference line as seen in the front view. For balance of layout refer

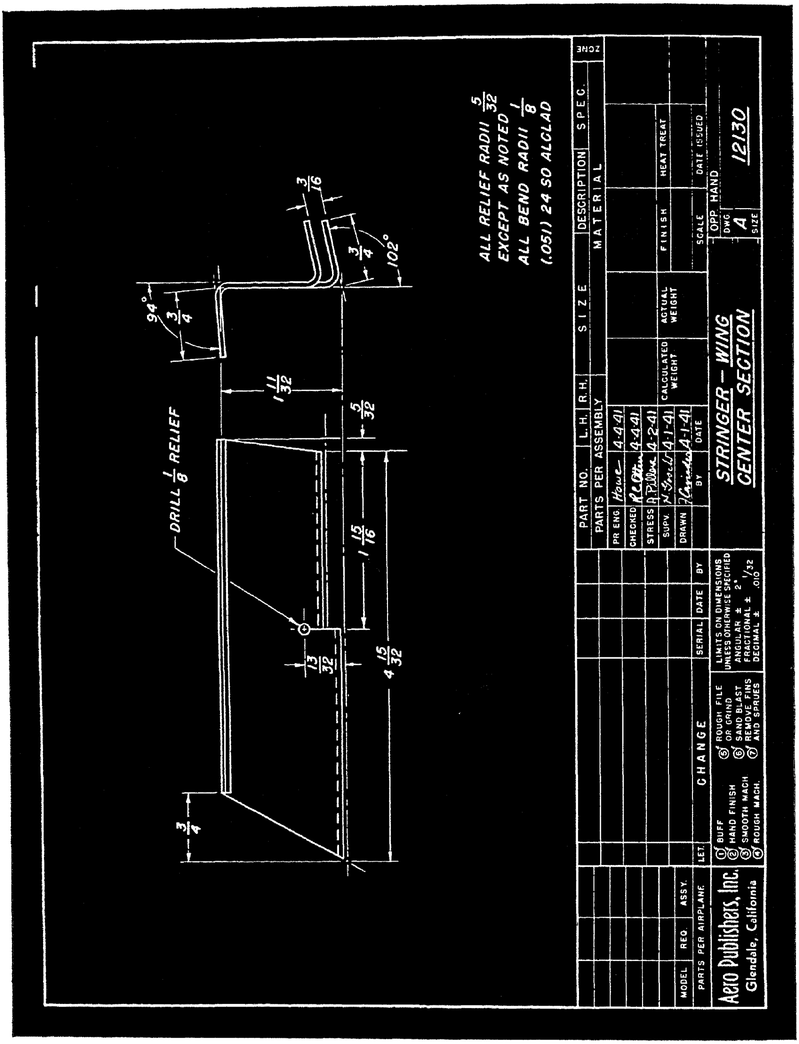


to Chapter 6 on development for bends more or less than 90°

Problem No. 12130

Title:

Stringer—Wing Center Section.

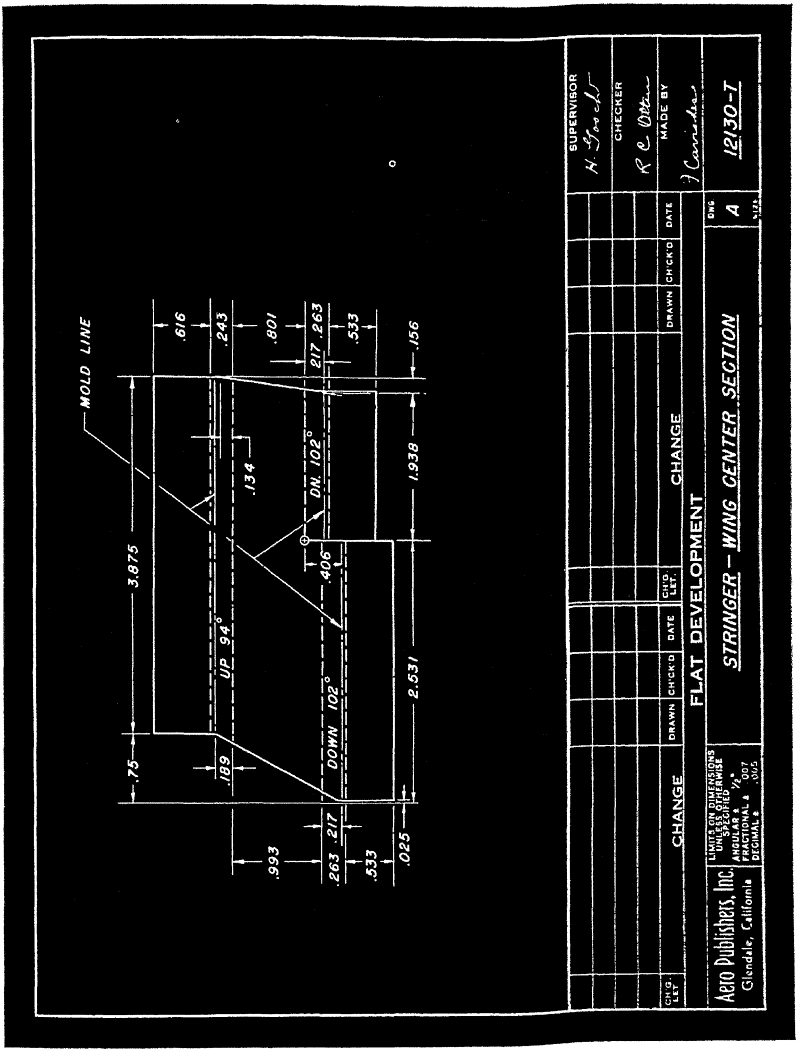


Object:

To develop a template for a part having two bends, extending in opposite directions and the flanges bent through an angle greater than 90°.

Procedure:

Lay out outline of part as seen in front view, thus establishing mold lines for each bend.

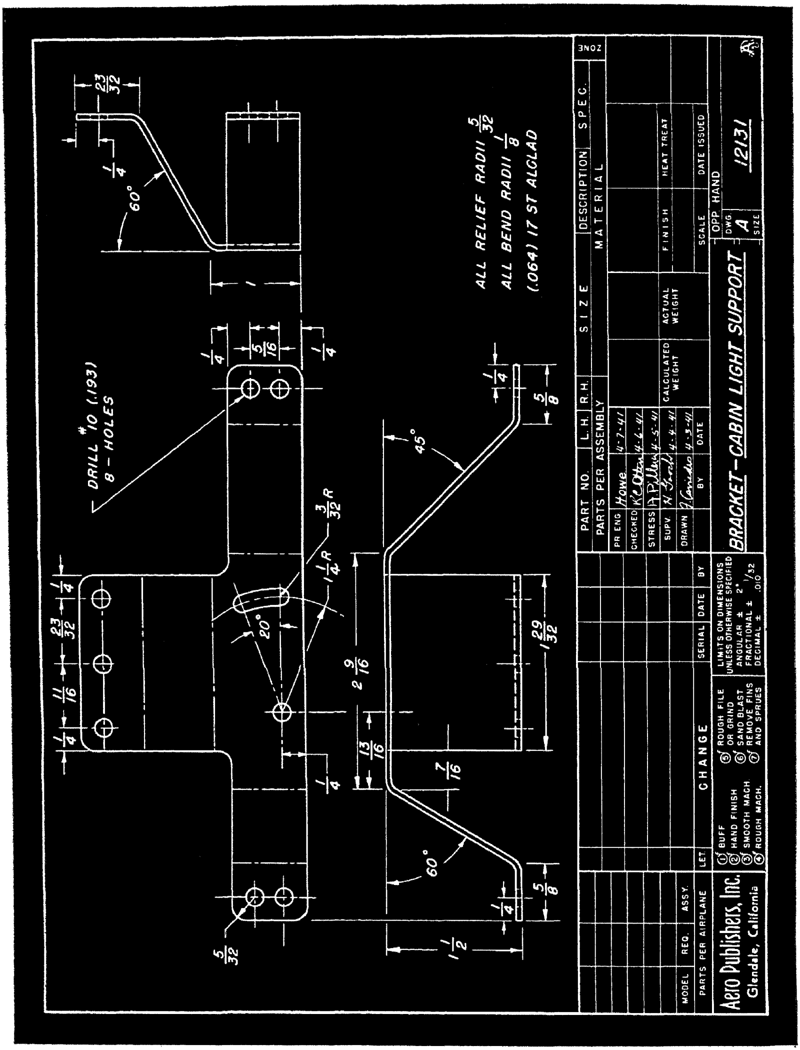


Observe that the top flange is dimensioned at the inside mold line, therefore from the top line of the layout we draw a bend line "Y" distance down. Calculate bend allowance for this flange

(Continued on page 250)

Problem No. 12131

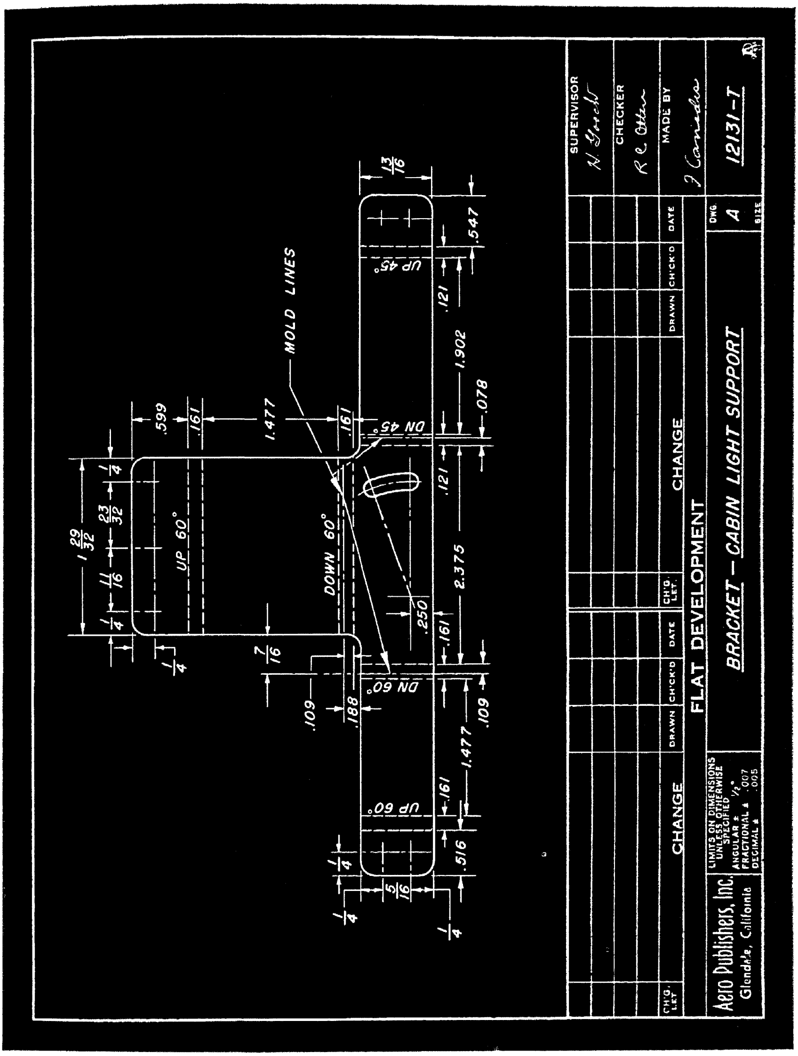
Title:
Bracket—Cabin Light Support.



Object:
Develop flat pattern for bracket.

Procedure:

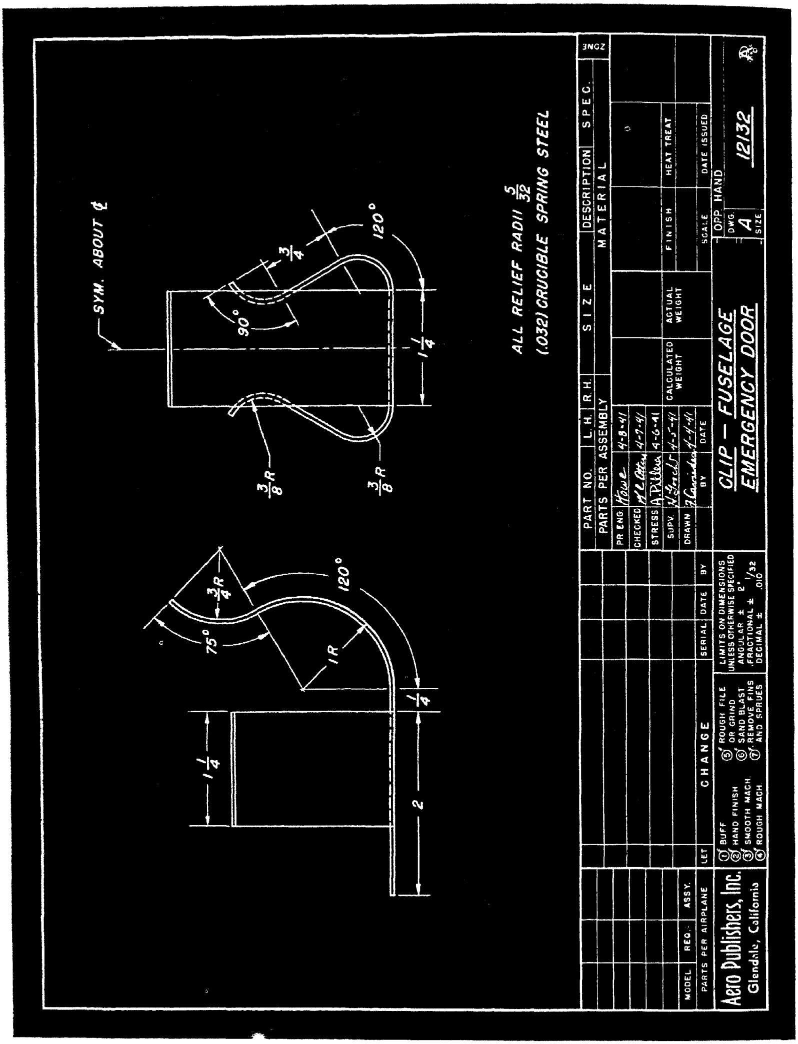
Similar to previous problems. Use Trigonometry to calculate missing dimensions.



Problem No. 12132

Title:

Clip—Fuselage Emergency Door.

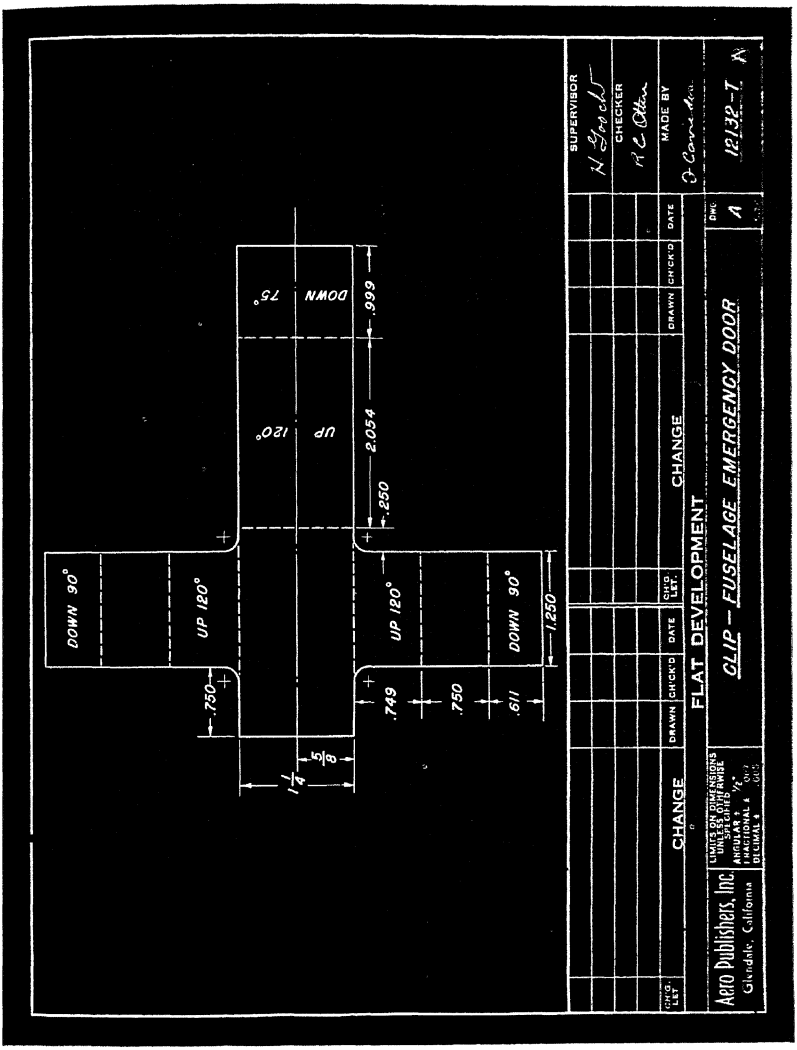


Object:

Develop template for clip.

Procedure:

All dimensions and bend angles are given, thus simplifying the development for this part. However, observe that the 1″ and

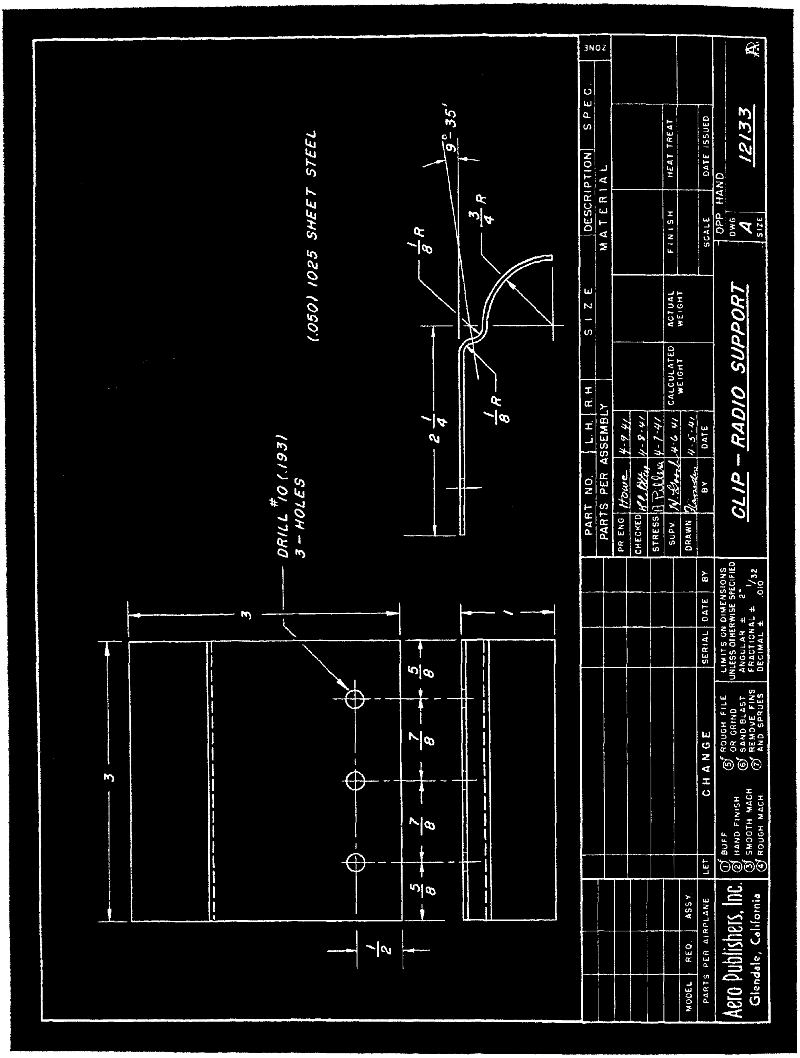


lower 3/8″ bend radii are to the outside surface of the metal. We must subtract the metal thickness from these radii and then calculate the bend allowance using these new bend radii. Note direction of bends on template.

Problem No. 12133

Title:

Clip—Radio Support.

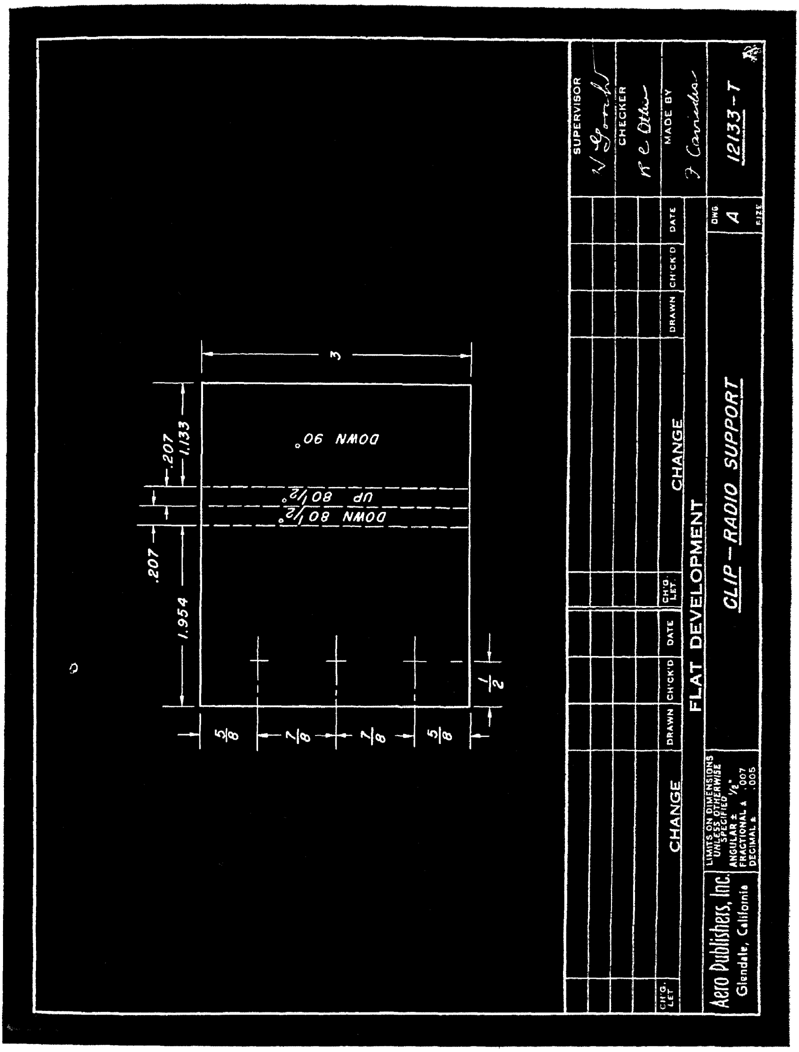


Object:

Develop flat pattern for clip.

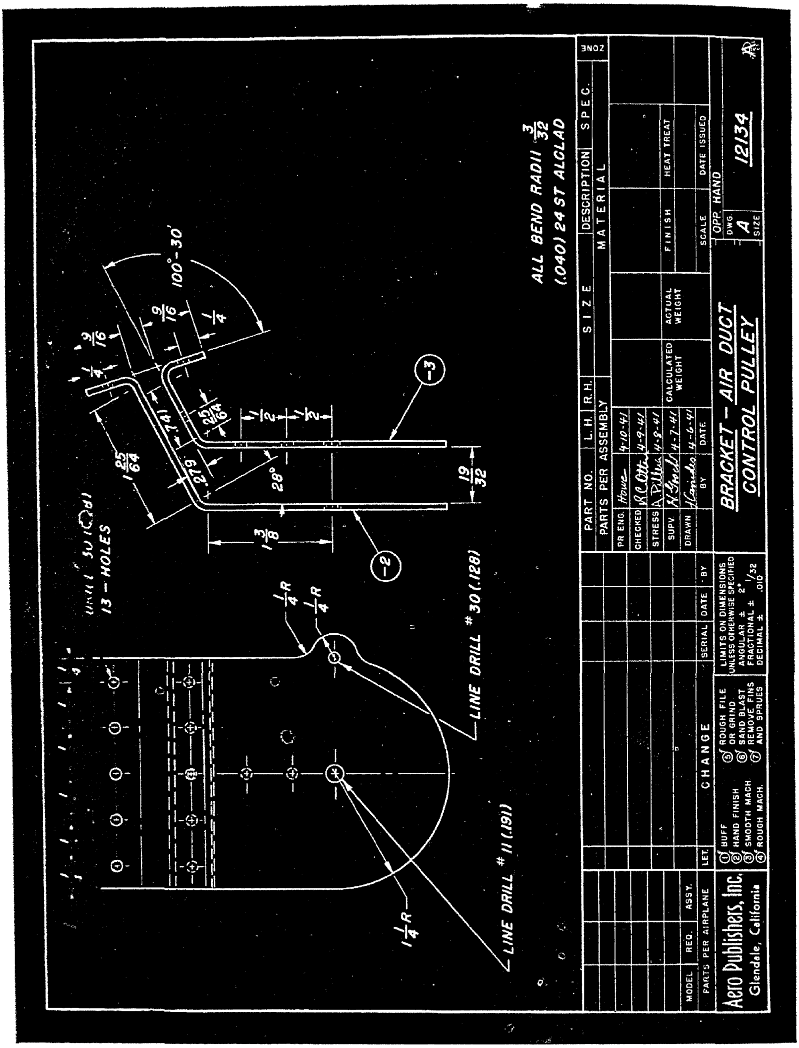
Procedure:

Similar to previous problems. Mark direction of bends on template.



Problem No. 12134

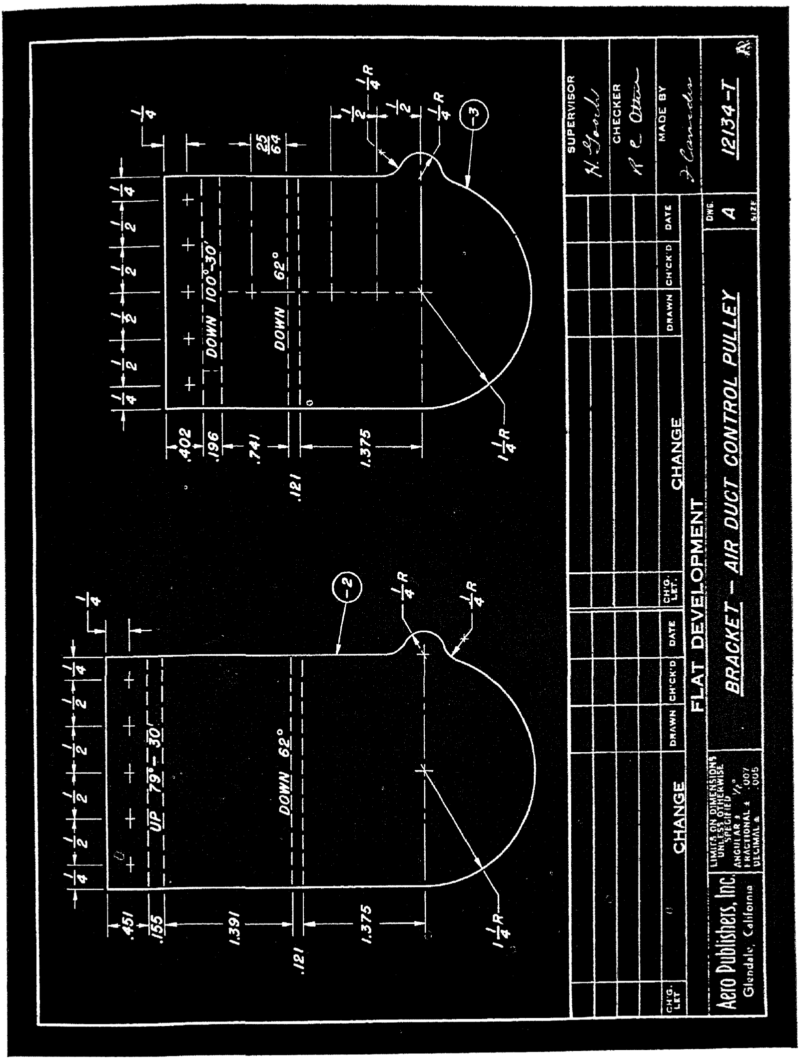
Title:
Bracket—Air Duct Control Pulley.



Object:
To acquire ability in developing templates from drawings which are dimensioned in a somewhat involved manner.

Procedure:

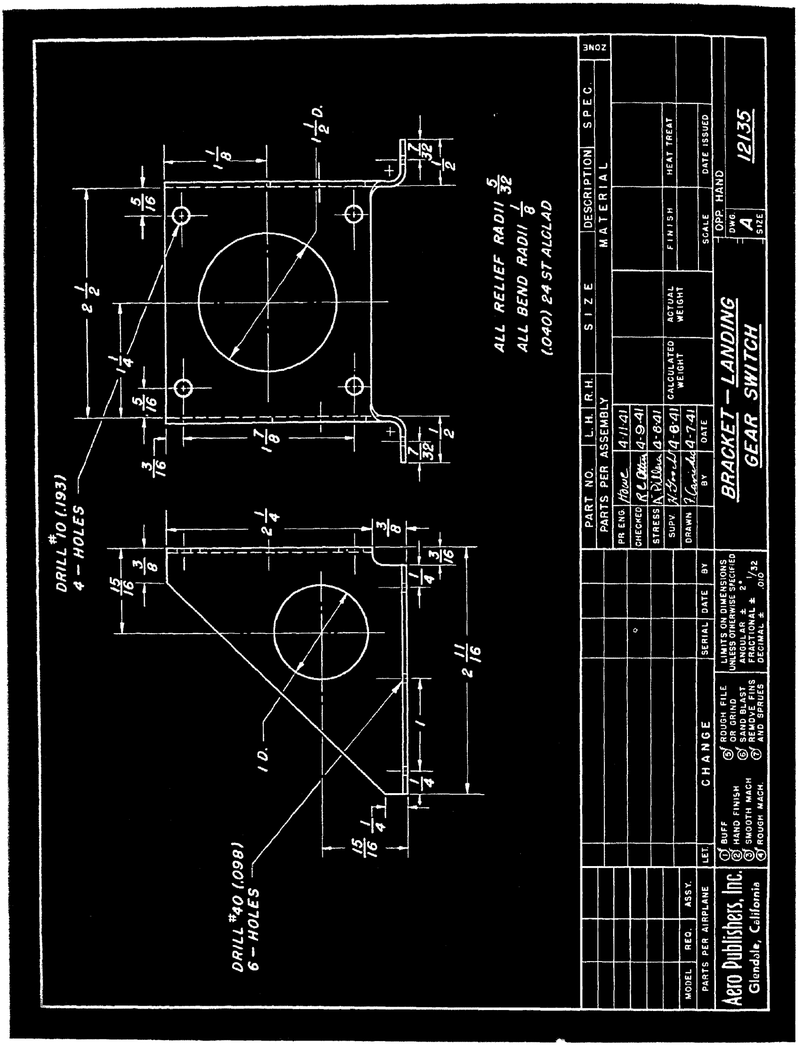
Similar to previous problems.



Problem No. 12135

Title:

Bracket—Landing Gear Switch.

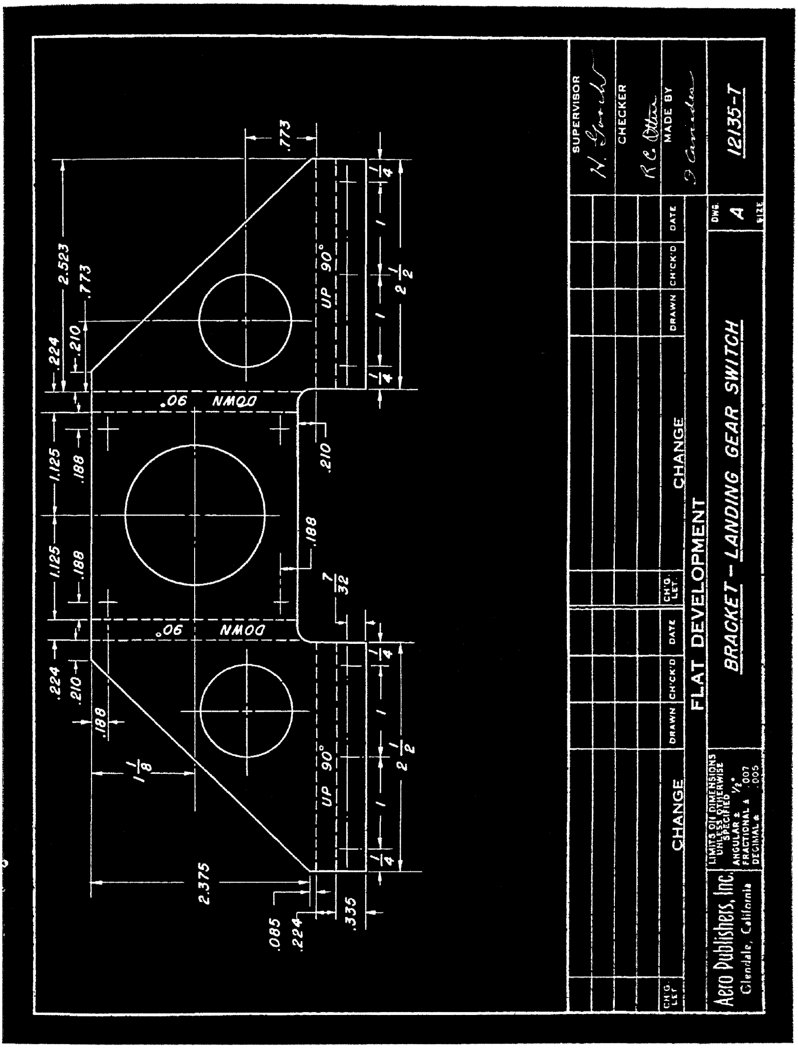


Object:

Lay out flat template for bracket.

Procedure:

Use the front view, in which we see the $1\frac{1}{2}''$ diameter hole, as the start of the pattern. Draw outline of two mold lines on



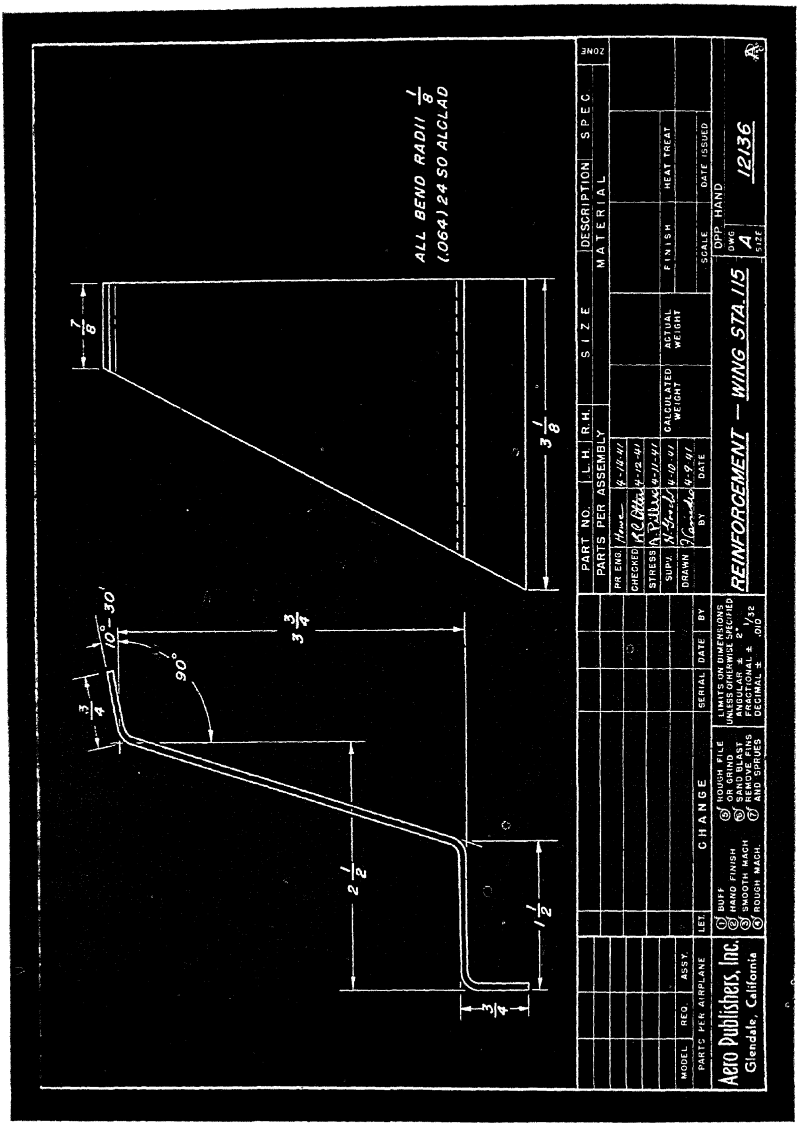
side and top and bottom edges as seen in this view. Draw bend lines in their correct position. Locate all dimensioned points in the side view by subtracting thickness plus radius from the hori-

(Continued on page 251)

Problem No. 12136

Title:

Reinforcement—Wing Sta. 115.

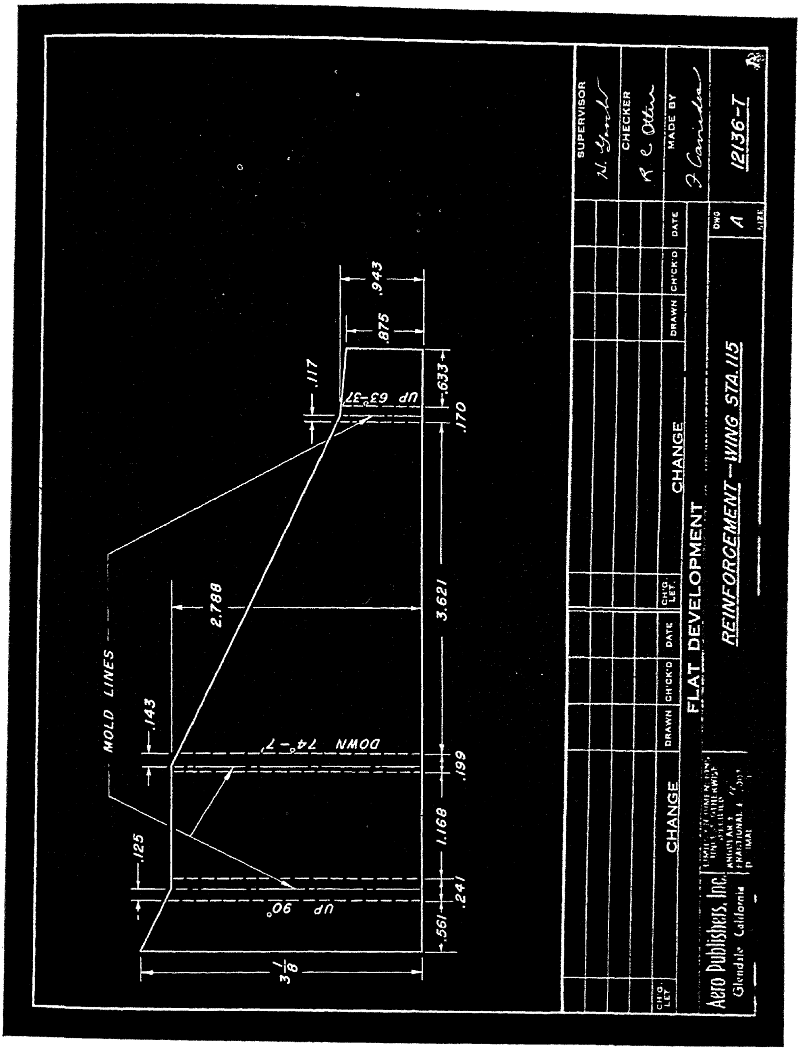


Object:

Develop flat pattern for reinforcement.

Procedure:

This part is dimensioned to mold lines which are on opposite sides of the metal. In order to determine the true bend angles



it is necessary to take all dimensions from one side of the metal. See Figure 8:1, page 251, for the method used to solve this problem.

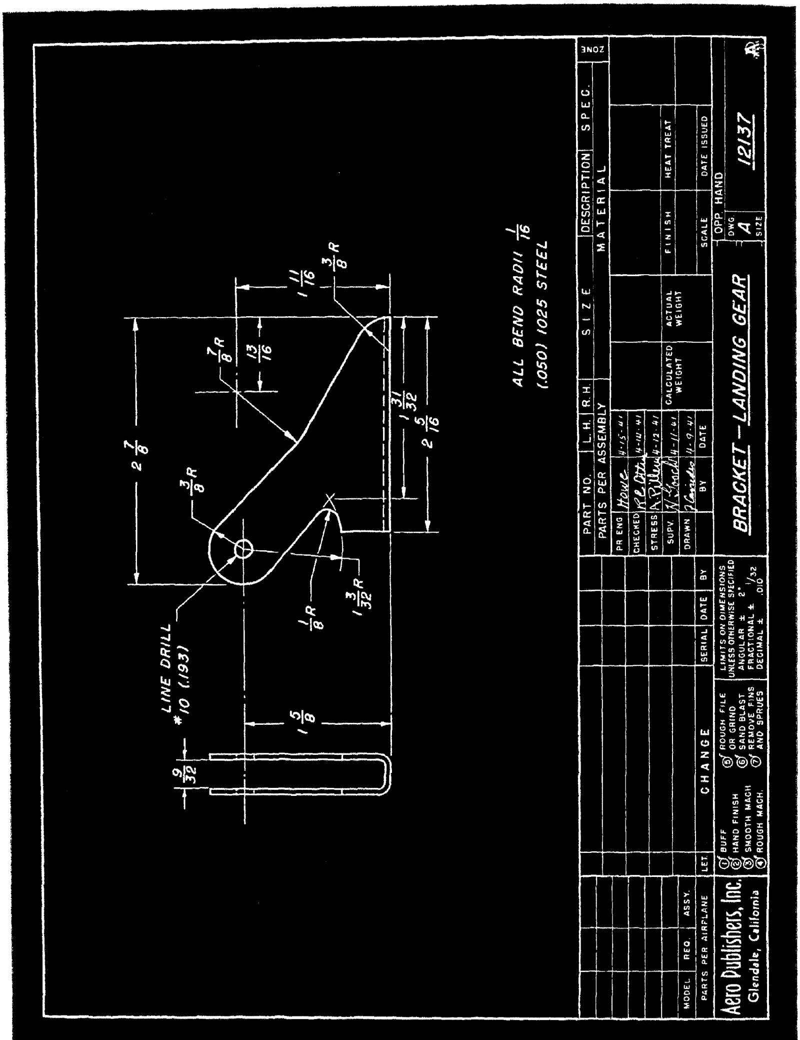
After the true bend angles and flat distance between bends

(Continued on page 251)

Problem No. 12137

Title:

Bracket—Landing Gear.

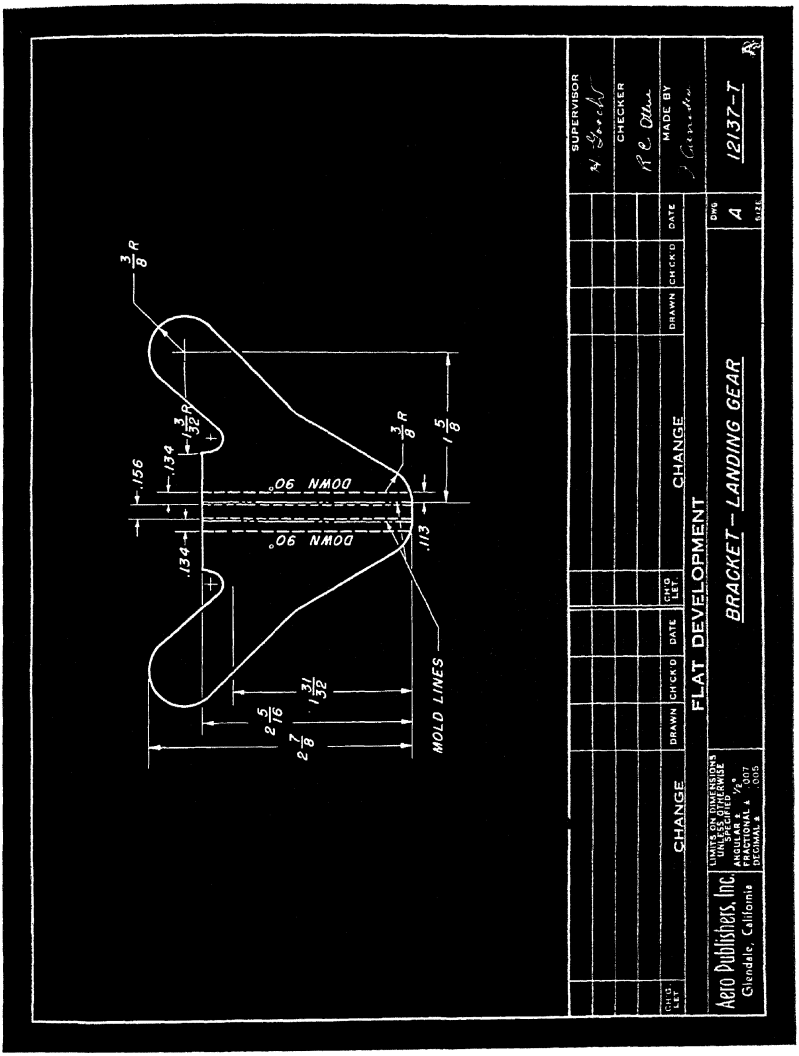


Object:

Develop flat pattern for bracket.

Procedure:

This part is symmetrical about its center line and can be developed from the center line or from the side view. Procedure

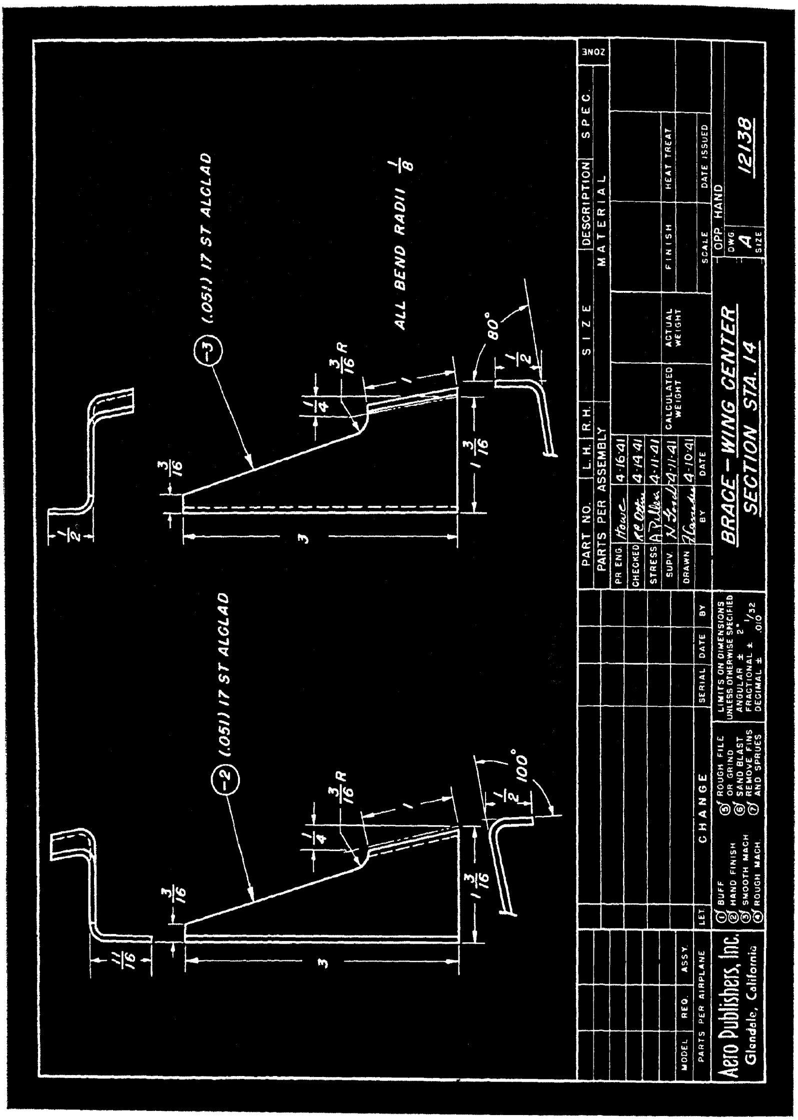


is similar to problem No. 12115.

Problem No. 12138

Title

Brace—Wing Center Section Sta. 14.

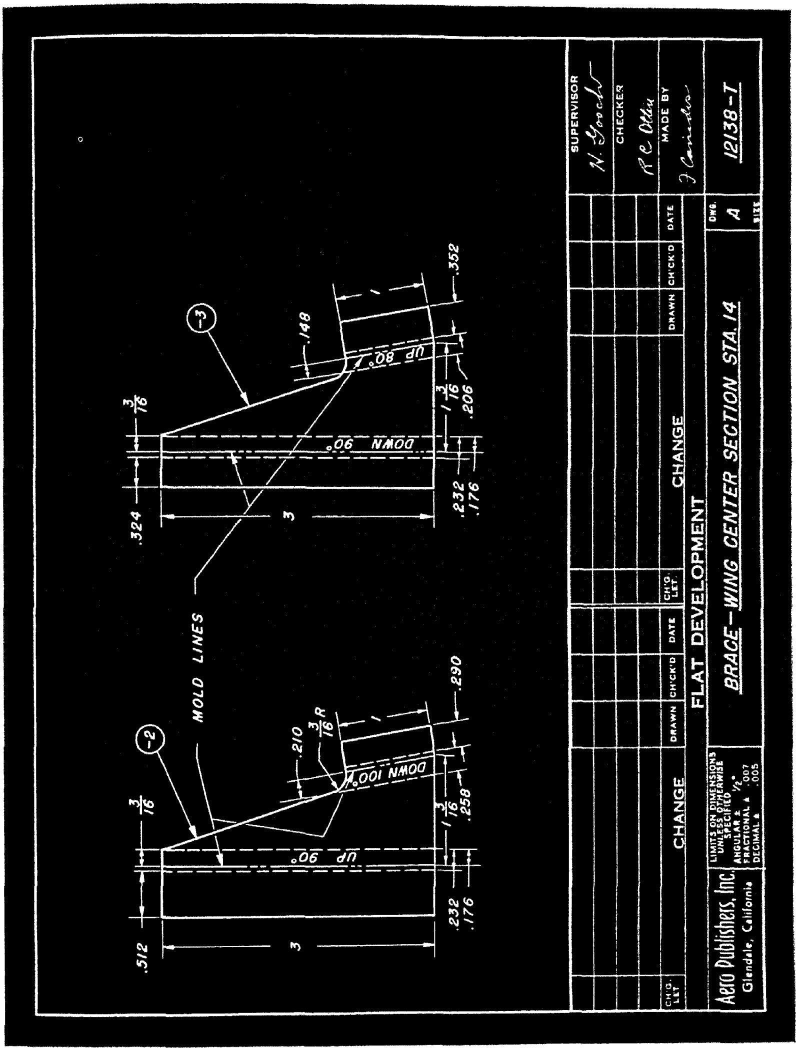


Object:

Develop flat pattern for brace.

Procedure:

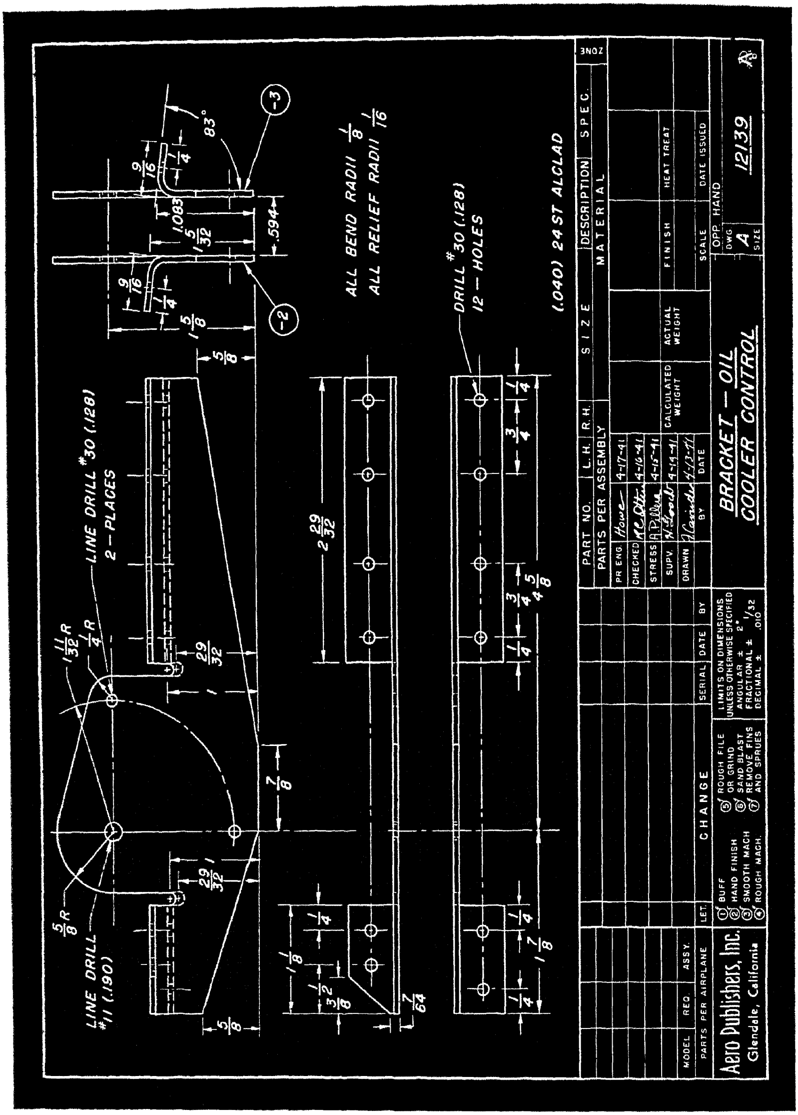
Procedure is similar to previous problems.



Problem No. 12139

Title

Bracket—Oil Cooler Control.

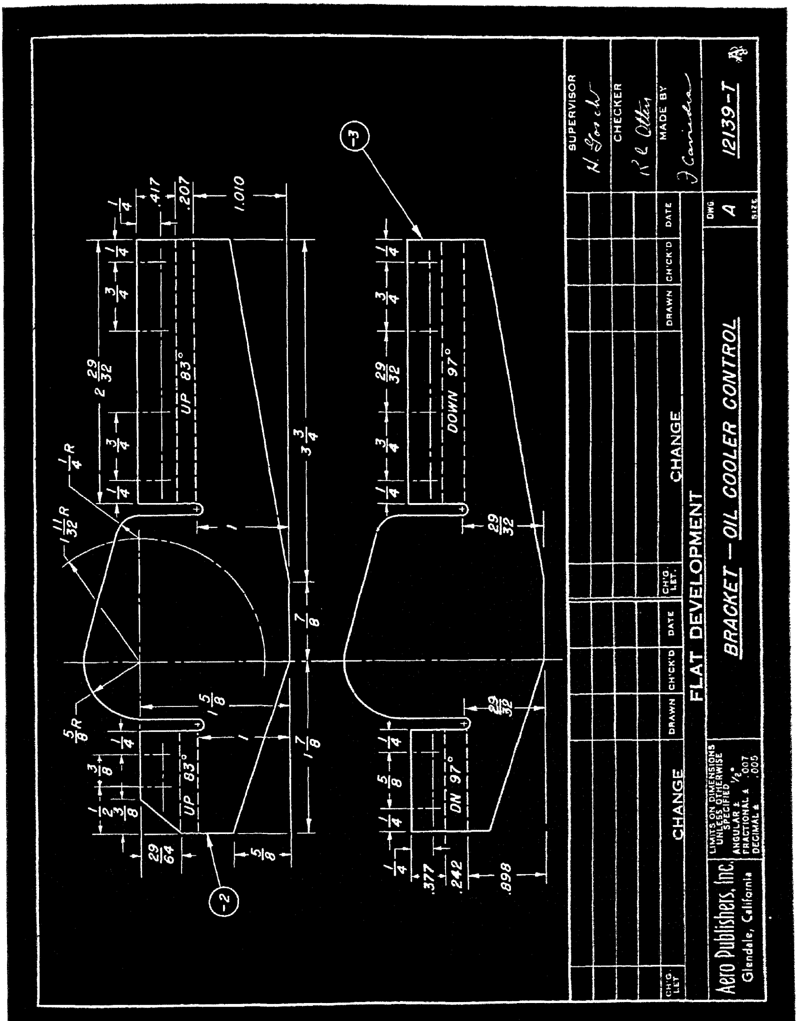


Object:

Develop flat patterns for -2 and -3

Procedure:

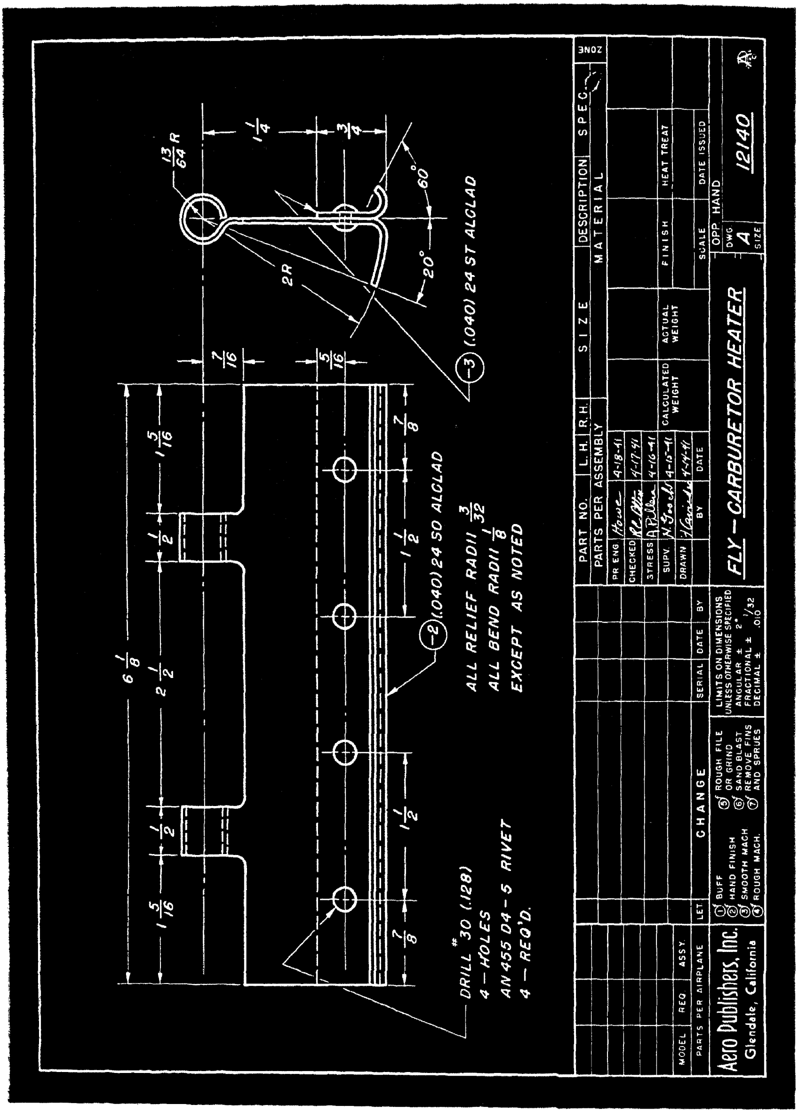
This is a review of previous problems.



Problem No. 12140

Title:

Fly-Carburetor Heater.

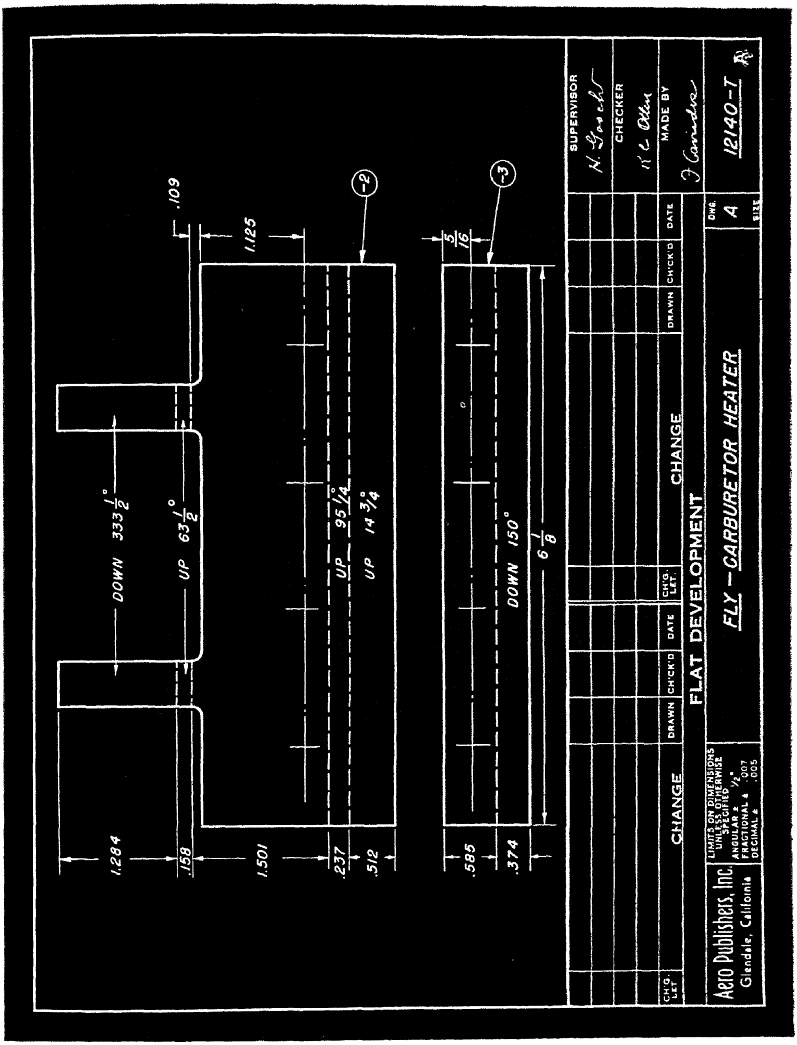


Object:

Develop flat patterns for -2 and -3.

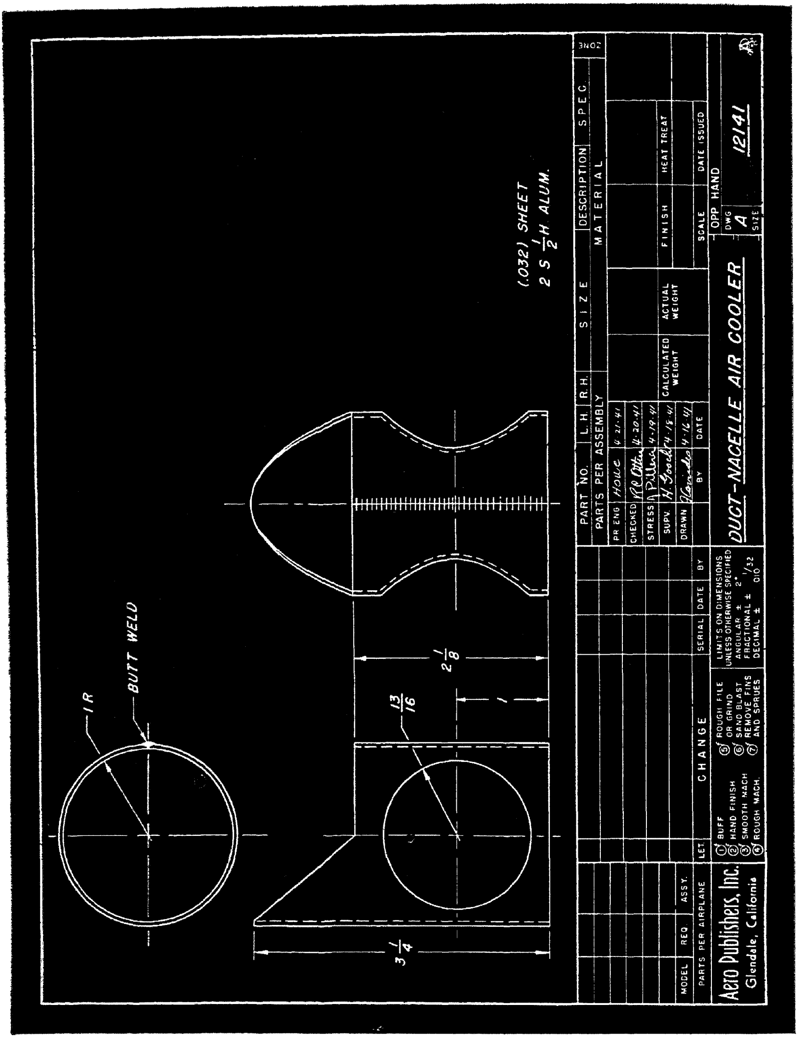
Procedure:

Calculate bend angles by the use of trigonometry. Note direction of bends on template.



Problem No. 12141

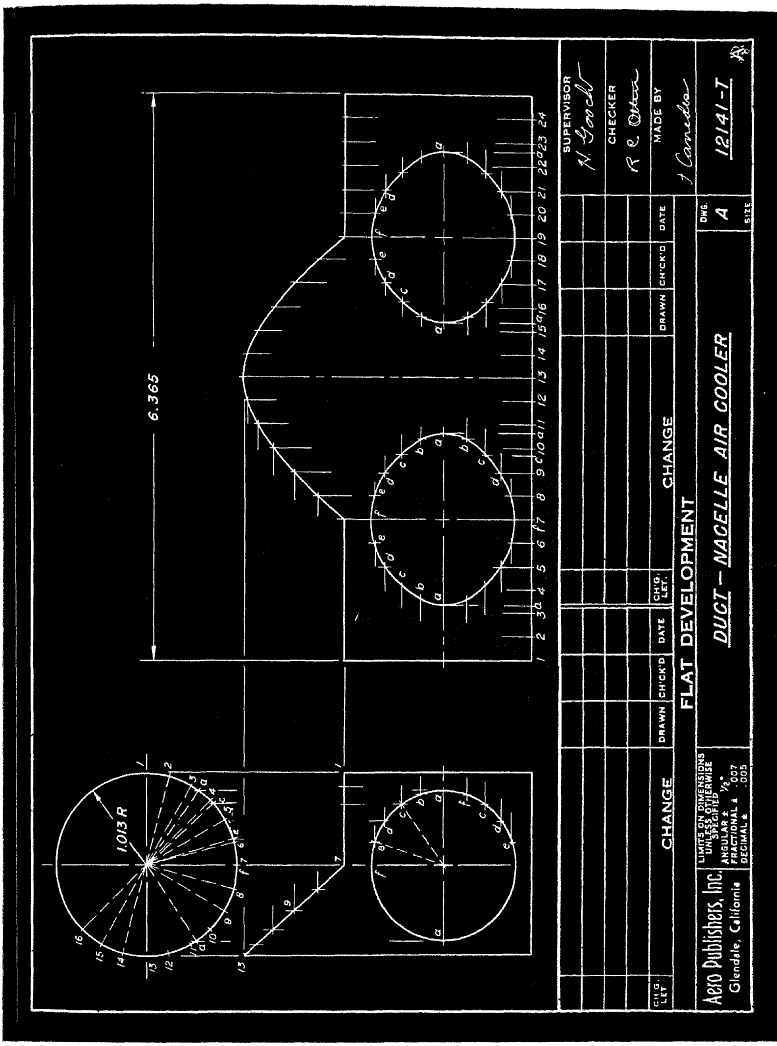
Title:
Duct—Nacelle Air Cooler.



Object:
To develop a template for the air duct by a combination of layout and calculation.

Procedure:

By the bend allowance formula determine the flat developed length to be 6.365". Use 6.365" as the circumference of the tube.



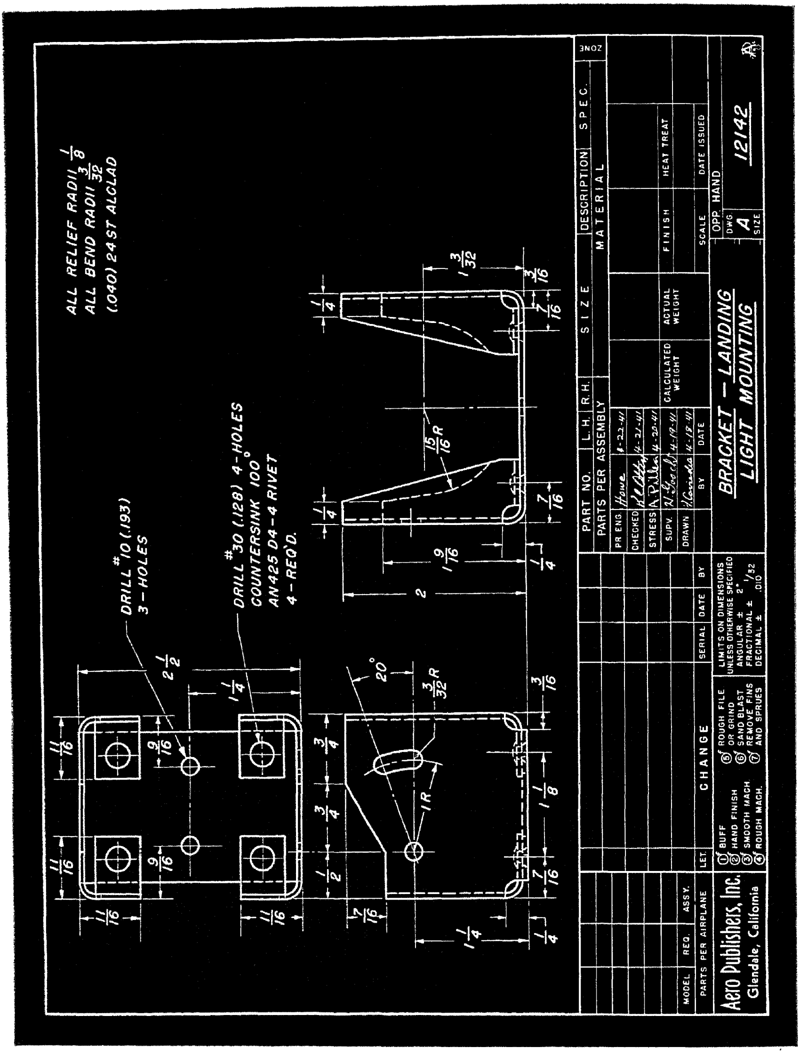
Dividing 6.365" by $2\pi = (2 \times 3.1416)$, 1.013" is obtained as the radius to use in our development. Using 1.013" as the radius, lay out full size plan and side views of the tube in their correct

(Continued on page 251)

Problem No. 12142

Title:

Bracket—Landing Light Mounting.

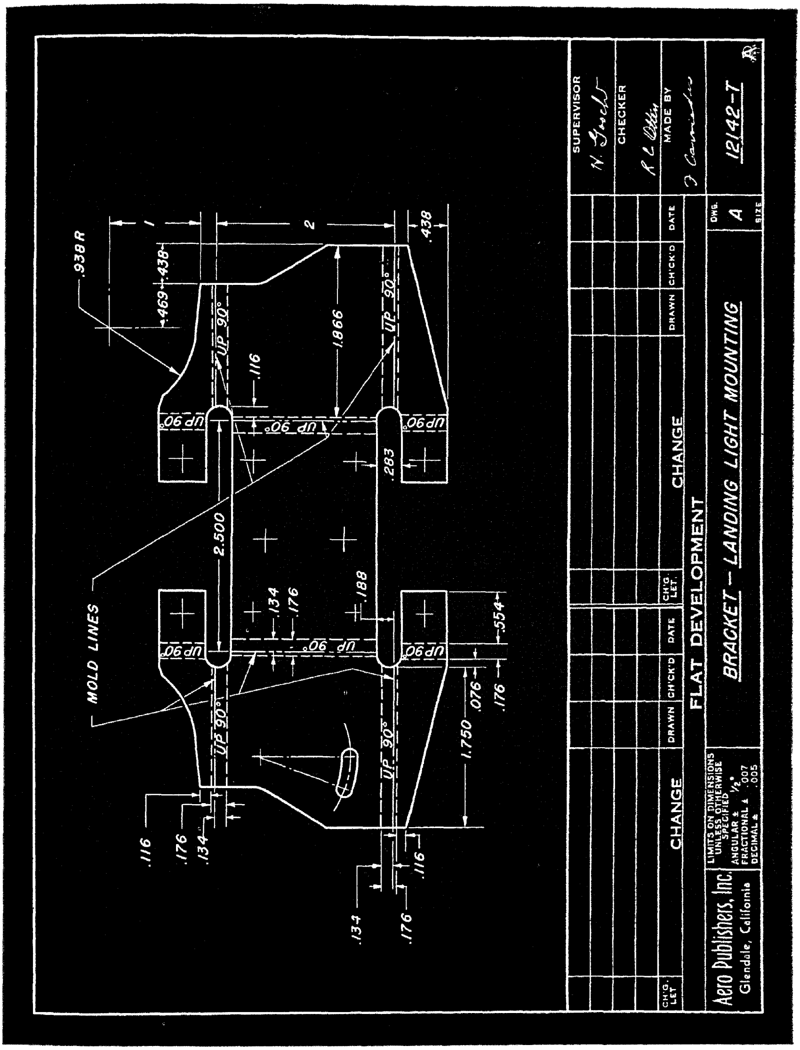


Object:

Develop flat pattern for bracket.

Procedure:

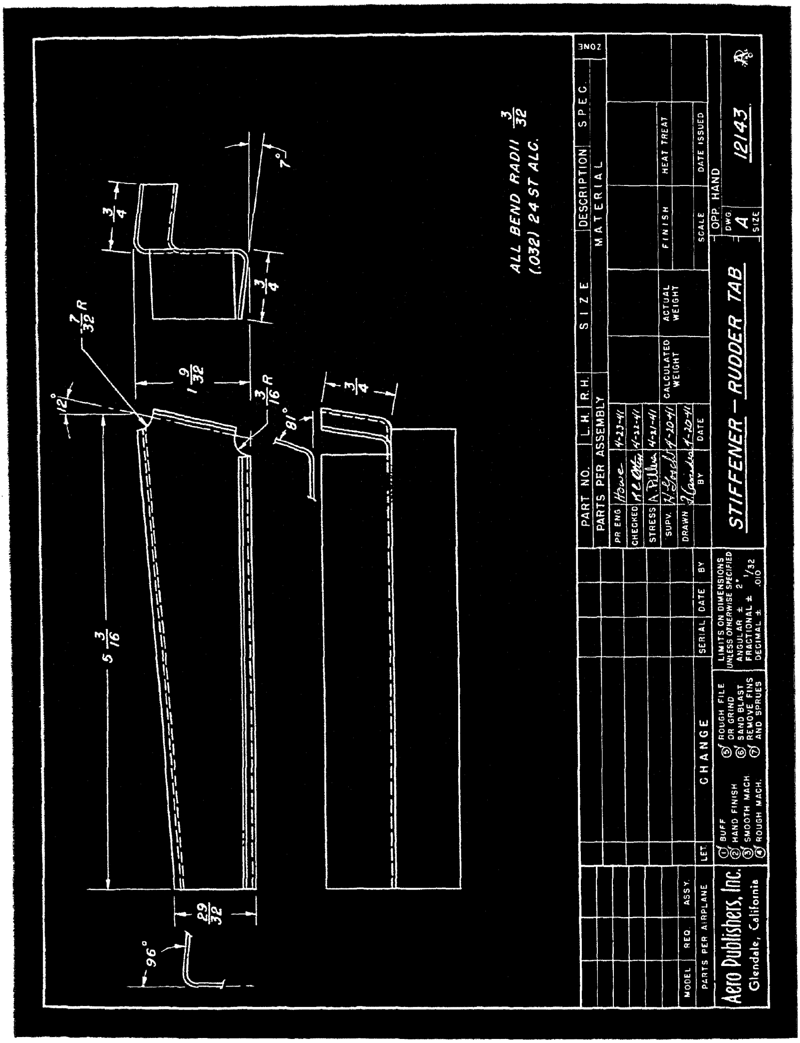
The flanges are bent back to fasten to the bottom of the part. Therefore the length of the sides which have flanges will be 2"



minus the metal thickness. Development will be similar to previous problems. Note direction of bends on template.

Problem No. 12143

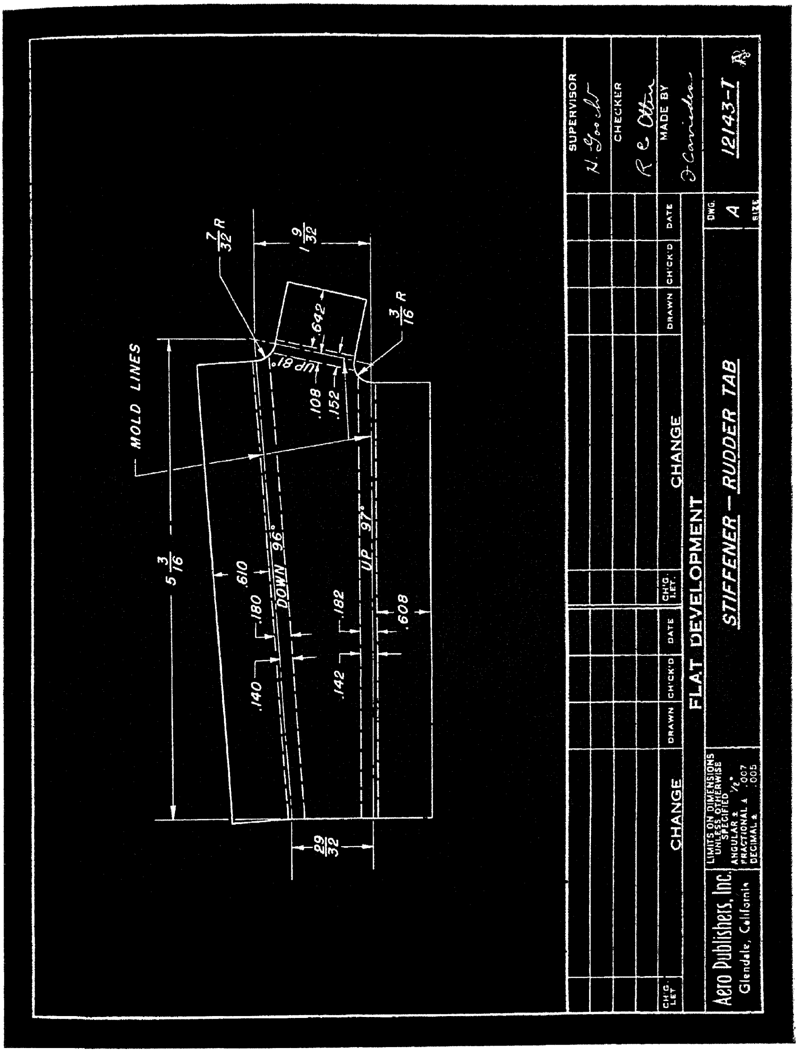
Title:
Stiffener—Rudder Tab.



Object:
Layout flat pattern for stiffener.

Procedure:

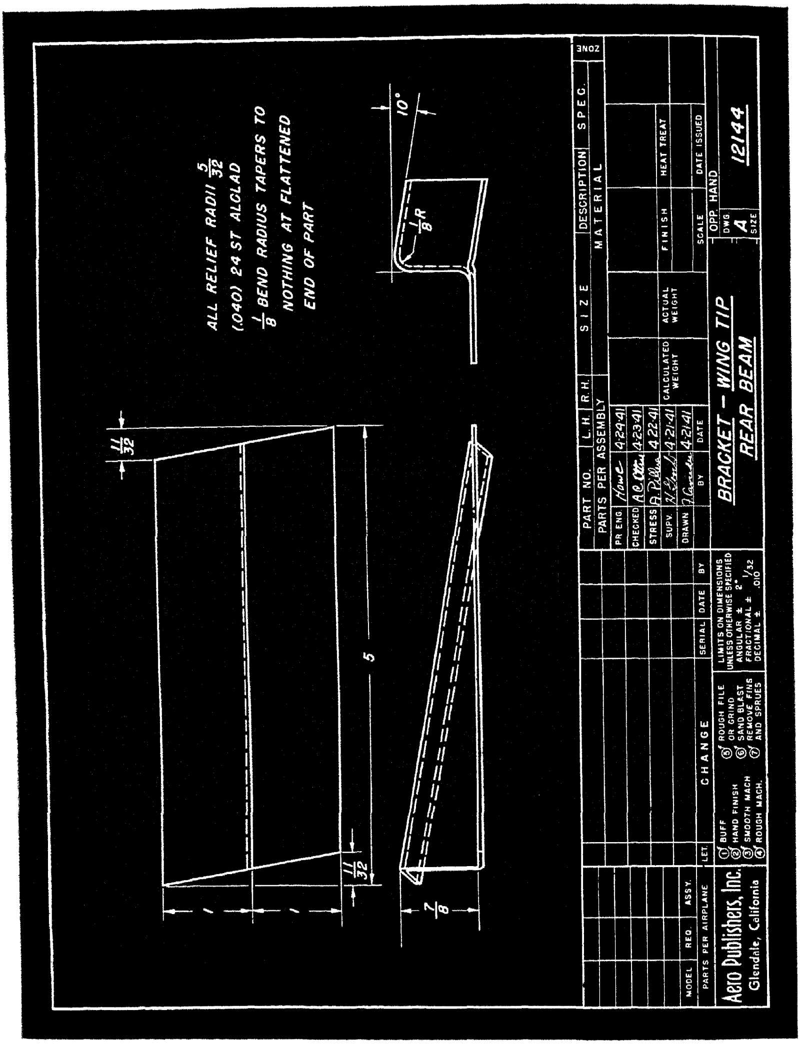
Similar to previous problems.



Problem No. 12144

Title:

Bracket—Wing Tip Rear Beam.

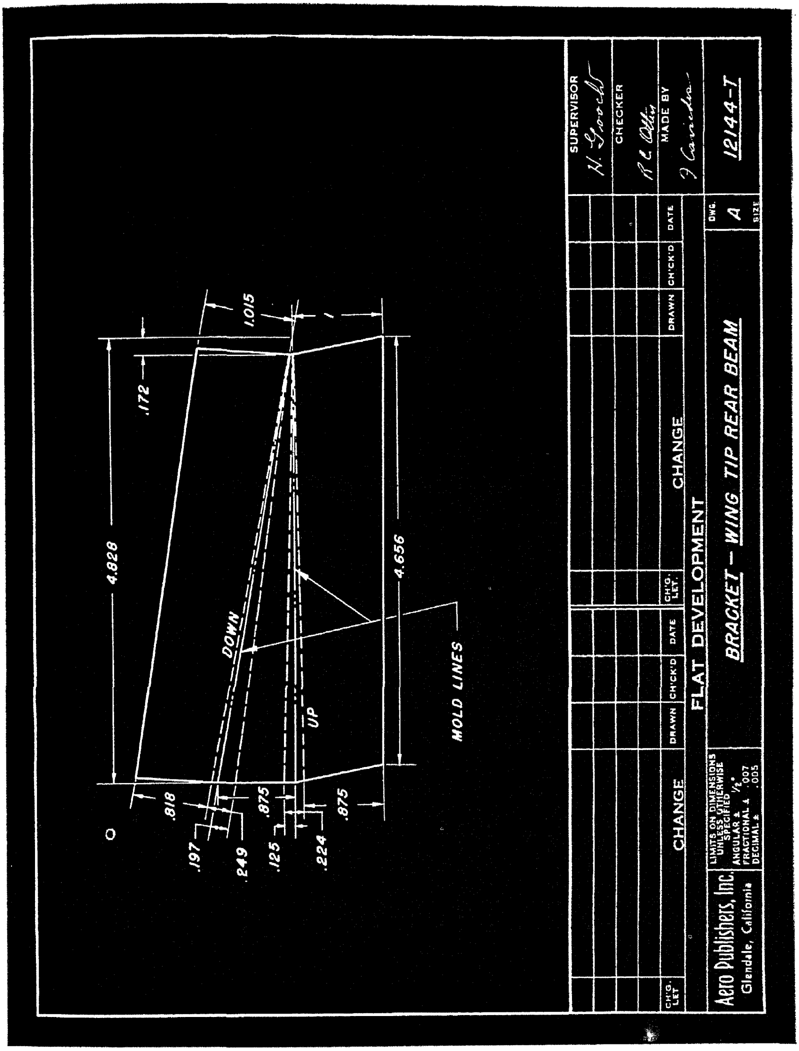


Object:

Develop flat pattern for bracket.

Procedure:

Observe note on drawing explaining bend radius. In this case use bend allowance for 100° on the 1/8 bend radius at the left



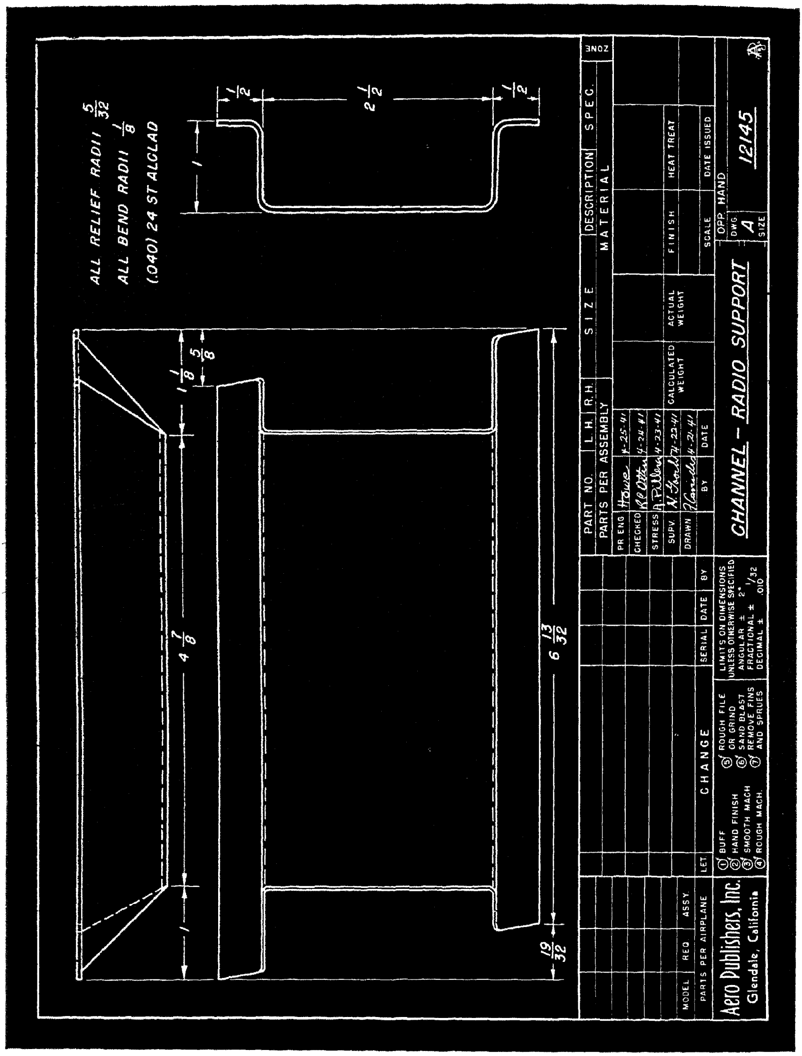
end of the part and taper the bend lines to a point at the other end. Determine shape of flange ends by locating the flange in its formed position in the front view in relation to its mold line.

(Continued on page 252)

Problem No. 12145

Title:

Channel—Radio Support.

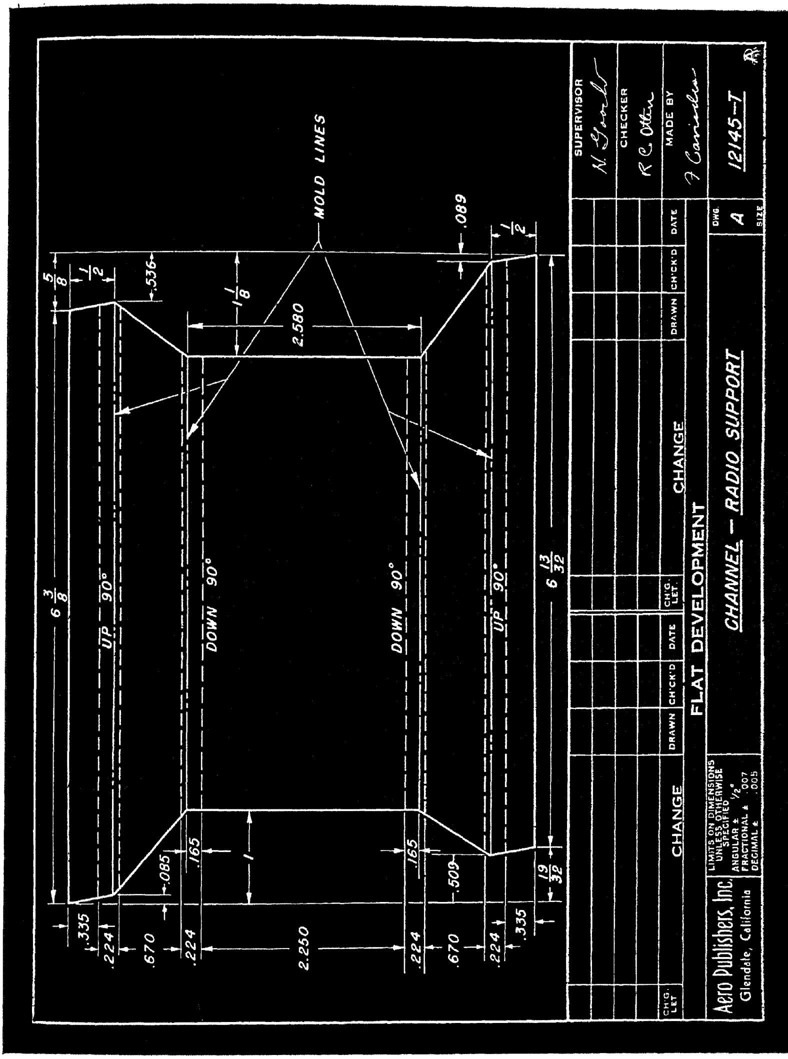


Object:

Develop flat pattern for -2 and -3.

Procedure:

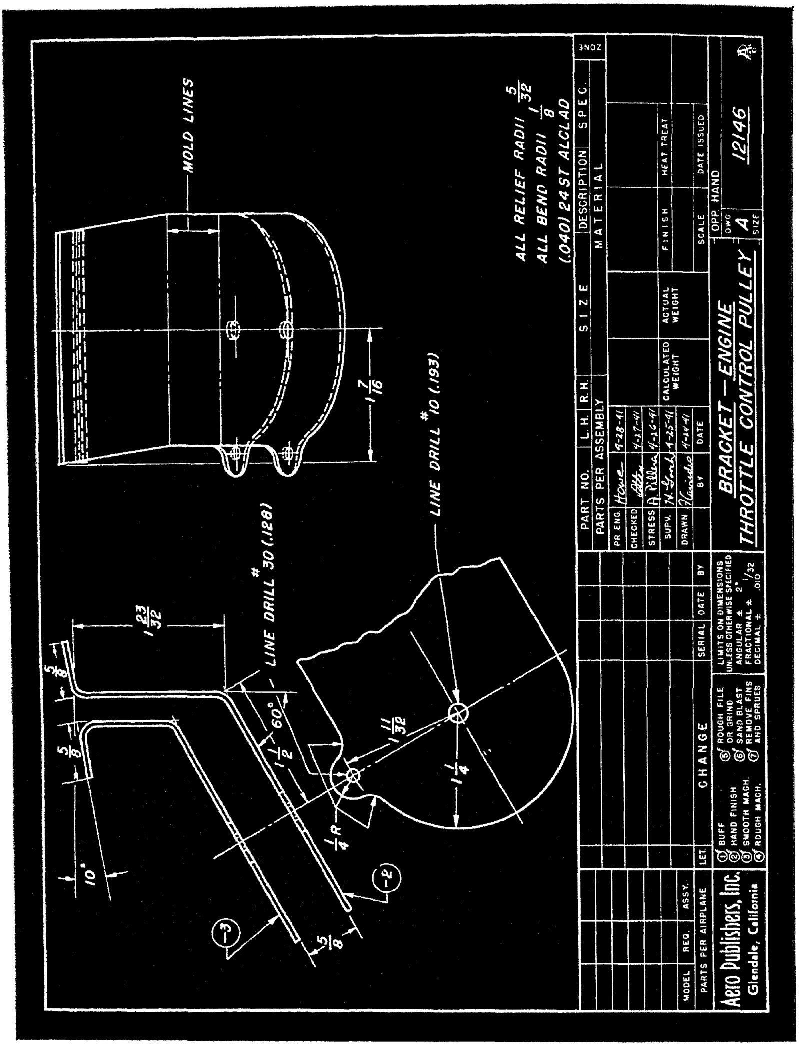
Similar to previous problems. Note that one template is used to make both the left and right parts. Only difference is direction



of bend as marked on the template.

Problem No. 12146

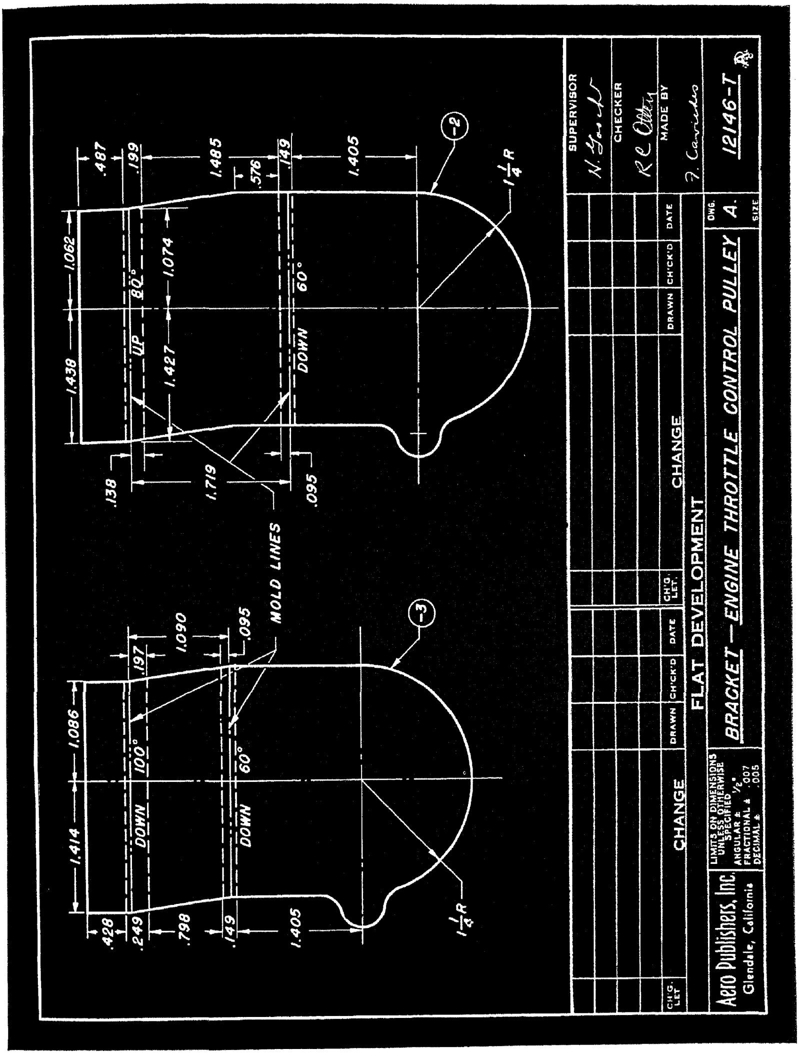
Title:
Bracket—Engine Throttle Control Pulley.



Object:
Develop flat patterns for -2 and -3.

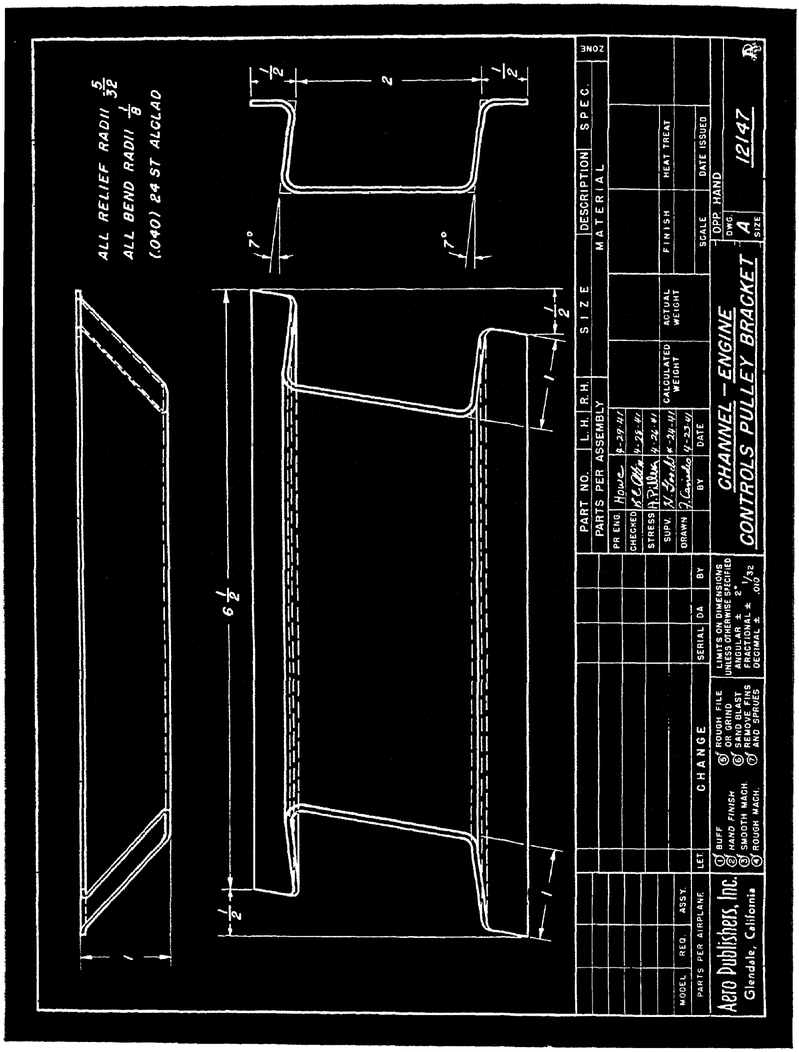
Procedure:

By the use of trigonometry solve for all dimensions necessary to lay out flat pattern. Similar to previous problems.



Problem No. 12147

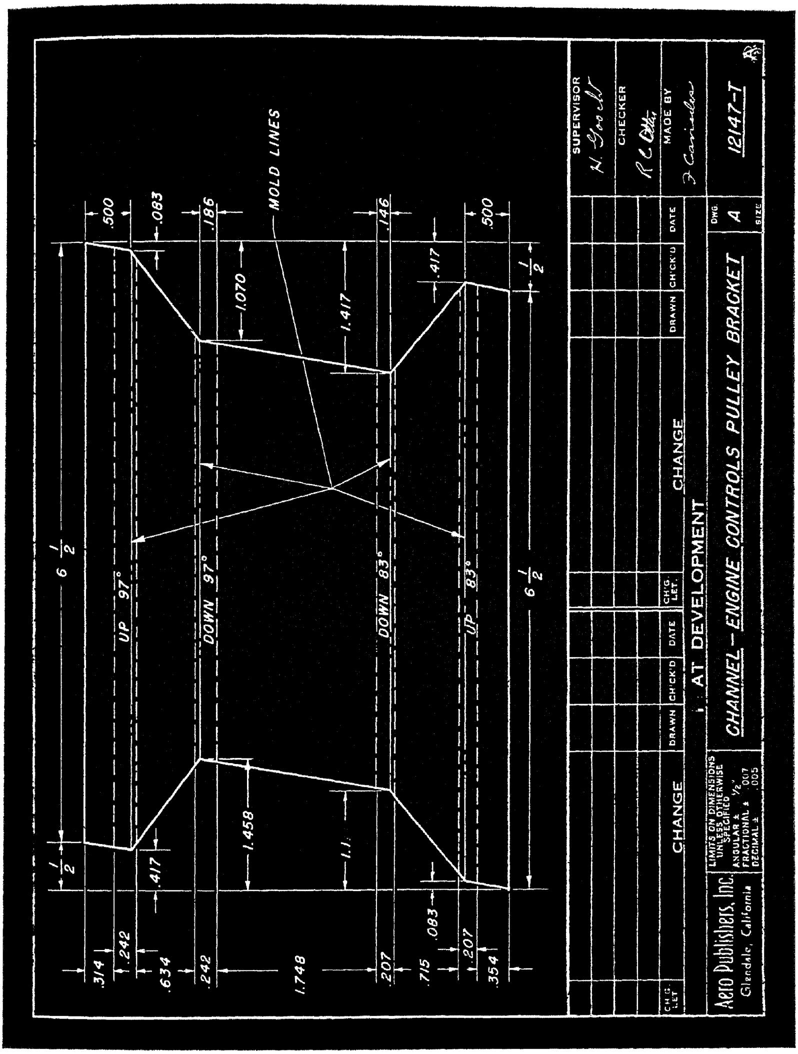
Title:
Channel—Engine Controls Pulley Bracket.



Object:
Develop flat pattern for channel.

Procedure:

Similar to previous problems. Calculate all dimensions needed to complete the flat pattern. Refer to previous problems and



Chapter 6 for diagonal cuts.

Problem No. 12101, Continued

Locate the centers of the five $\frac{3}{16}''$ diameter holes by using the vertical and horizontal dimensions from the reference lines.

Problem No. 12102, Continued

ter of the strap and all vertical dimensions will be measured from this line.

When all center of radii have been located according to dimensions on the print they should be very lightly prick-punched. By using a pair of dividers or a compass which has been set to the proper radius, the radius can be drawn in. Draw straight lines tangent to all radii, thus completing the template layout.

Problem No. 12103, Continued

straight line from this point to the end where it is $\frac{9}{16}''$ wide. Locate the center of the $\frac{5}{8}''$ radius by drawing an arc of $1\frac{11}{16}''$ radius, which is equal to the $1\frac{1}{16}''$ radius plus the $\frac{5}{8}''$ radius. Locate this arc near the intersection of the tapered line with the $1\frac{1}{16}''$ radius. Now draw a line parallel to, and $\frac{5}{8}''$ from the tapered line. The intersection of this line with the $1\frac{11}{16}''$ radius is the center of the $\frac{5}{8}''$ radius.

The pilot holes for the four No. 40 holes can be located by use of a protractor or by stepping it off with a pair of dividers. Six equal spaces in 90° stepped off around the radius will locate each mark at 15° intervals. This gives the location of the first hole, and the others are at 90° intervals from that location.

Problem No. 12104, Continued

to the horizontal line.

The proper procedure for obtaining the location of this bend line has been previously described in Chapter 6.

The second bend line will be drawn parallel to and the proper distance from the first bend line. This distance shall be obtained by use of either the Bend Allowance Chart or the Empirical Formula, which has been outlined in Chapter 6. The fourth horizontal line will be drawn in its correct relationship to the last bend line and determines the end of the developed template.

Problem No. 12105, Continued

end of the template. The first bend line shall be located by a horizontal line and its distance above the lower end of the template shall be determined by subtracting the sum of the thickness of the metal plus the bend radius from the $1\frac{5}{8}''$ dimension. (See Chapter

6.) The second bend line will be parallel to the first one, and its relationship to the first bend line will be determined from the Bend Allowance Chart. The fourth line, which determines the end of the developed part will be drawn parallel to the bend lines, its location from the second bend line is determined by subtracting the sum of the thickness plus the radius from the 3/8" dimension which is the width of the flange.

The single lower .140 drill size hole will be located by the 3/8" and the 3/4" dimensions. The two .166 drill size holes will be located by drawing two vertical lines parallel to the two sides of the template and 5/16" in, as shown on the blueprint. The other dimension which is necessary for these two holes shall be determined by subtracting the 1/2" dimension from the 1 5/8" dimension and drawing a horizontal line 1 1/8" from the lower template line. The two 3/32 drill size holes are located by a horizontal line 3/16" from the top of the template and by using the horizontal dimensions, 1/4" and 1".

Problem No. 12106, Continued
eliminate the necessity of making numerous subtractions when locating the holes.

Problem No. 12107, Continued
be called out "Bend Up L.H.," "Bend Down R.H." Location of bend lines similar to problem 12104—see Chapter 6.

Problem No. 12108, Continued

For example use the callout 1 1/16" x 1 5/16" x 4" channel (–4). When this type of information is called out it is understood that a channel 1 1/16" x 1 5/16" x 4", .040 thick with 1/8 radius is to be developed. (See 12108-T, page 177)

The only difference if –2 (.025) and –3 (.032) were to be used would be in the amount of B. A. and the distance between them, because the basic overall dimensions of the part remain the same.

Procedure for developing the width of this channel is the same as for a 90° angle except that there will be two bend allowances and the portion between the bends will be computed by subtracting the sum of two thicknesses plus two radii from the 1 5/16" dimension.

Problem No. 12110, Continued
Add the bend allowance for .064 material and a 1/4" radius which has been computed for a 180° bend. Locate all center punch marks.

Problem No. 12111, Continued

bend allowance for .040 material using a ⅛" radius will be computed and by measuring this distance from beginning of the bend toward the outside of the template, the end of the bend will be located for each flange.

Subtract the sum of the metal thickness plus the radius from the $\frac{9}{16}$" dimension which is the width of the flange, the remainder, which is the flat portion of the flange, shall be added to each of the three sides.

The part now being fully developed, it will be necessary to cut the reliefs on the two corners. Draw a line horizontally through the part $\frac{45}{64}$" from the base line, also draw vertical lines parallel to the sides, ¼" inside each mold line. These lines establish the end cuts on the flanges. Now draw $\frac{5}{32}$" radii tangent to the opposed flange ends.

Problem No. 12115, Continued

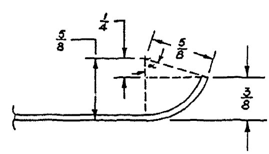
Subtract metal thickness plus radius from horizontal dimensions given from mold line in side view. Layout these new dimensions from outside bend lines to locate holes and outline of two sides.

Problem No. 12116, Continued

side view, one at 2¾ above horizontal line, the other .578 below upper end of flat pattern, determine from the side view where the cut intersects these mold lines and locate these points on the mold lines in the flat pattern. See Chapter 6. Indicate direction of bends and locate holes.

Proposition No. 12124 Continued

subtracting, (metal thickness plus ¾ radius plus side opposite α) from the 2⅜" dimension. End developments are as shown in accompanying figure.



$\frac{ADJ}{HYP} = COSINE\ \alpha$, THEREFORE

$\frac{.250}{.625} = .400 = COSINE\ \alpha = 66°25'$

Problem No. 12130, Continued

and draw a line this distance above the first bend line. Add the flat portion of the flange, determined by subtracting "Y" from the ¾".

The two bottom flanges are dimensioned to the outside mold line, therefore we draw bend lines "X" distance above each of these mold lines. Calculate bend allowance for these bends and draw lines this distance below our first bend lines. Add flat portion of flanges, determined by subtracting "X" from the ¾" flange widths.

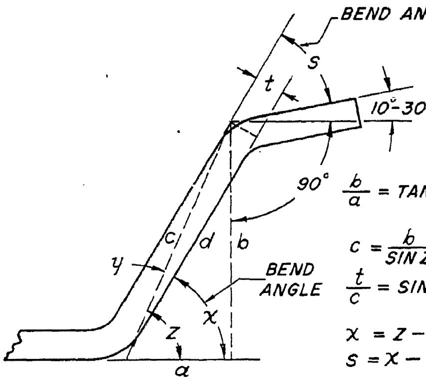
Diagonal cuts will be handled as in previous problems. Locate center of the relief hole and indicate direction of bends.

Problem No. 12135, Continued

zontal dimensions in this view and using these new dimensions from the two outside bend lines.

Problem No. 12136, Continued

have been determined the development will be similar to previous problems.



$$\frac{b}{a} = \text{TAN } Z, \therefore \frac{3.75}{1} = 3.75 = \text{TAN } Z; \quad Z = 75^\circ\ 4'$$

$$c = \frac{b}{\text{SIN } Z}, \therefore \frac{3.75}{.96623} = 3.881 = c$$

$$\frac{t}{c} = \text{SIN } y, \therefore \frac{.064}{3.881} = .01649 = \text{SIN } y; \quad y = 0^\circ\ 57'$$

$$x = Z - y, \therefore 75^\circ\ 4' - 0^\circ\ 57' = 74^\circ\ 7' = x$$

$$S = x - 10^\circ\ 30', \therefore 74^\circ\ 7' - 10^\circ\ 30' = 63^\circ 37' = S$$

Fig. 8:1

Problem No. 12141, Continued

relationship to each other, also lay out a development blank 2¾″ x 6.365″ in a horizontal projection from the side view. Divide the plan view and the development blank into 24 equal spaces, numbering each line and starting from the weld joint. From the intersection of these divisions with the circumference in the plan view, project vertical lines cutting through the side view. From the intersection of these vertical lines with the outline of the side view, project horizontal lines until they intersect the corresponding line in the development blank, thus getting a number of points which form the contour of the flat development.

For the development of the hole through the tube the procedure is similar except the hole in the side view is divided into equal spaces a, b, c, etc. These points are then projected vertically into the plan view giving points a, b, c, etc., on the circumference, and horizontally into the development blank, giving

horizontal lines a, b, c, etc. From the plan view determine the distance from the weld point around the circumference, to points a, b, c, etc. Use these distances to locate vertical lines a, b, c, etc., in the development blank. The intersection of the vertical lines a, b, c, etc., with the horizontal lines a, b, c, etc., establish points which determine the contour of the hole cutout in the flat pattern.

Problem No. 12144, Continued

Project a line from this formed position, perpendicular to the mold line until the edge of the flange in the flat pattern is intersected. Draw a line from this intersection to the mold line at the end of the part. This line is the shape of the flange end.

CHAPTER IX

PHOTOGRAPHIC REPRODUCTION OF TEMPLATES

At this time it is not possible to make an estimate of the probable extent to which the new loft photo system will go in template making. It is apparently a permanently established proposition in several of the larger factories. It has been predicted that it will eliminate the need for a great number of template makers but in any event it is not likely that a good template man will ever find his trade of no value to him.

The loft photographic system is not one where the impossible is attainable, nor is it attempted. A great deal of loss of time and duplicated work is eliminated however, because after the engineering department has once laid down the full sized line work, it is not necessary to manually reproduce any portion of it. Several aircraft factories have done some development work on similar photographic methods, namely—Glenn L. Martin, Lockheed Aircraft Corporation. Use of a specific case for a discussion of the system we will follow the details of the system used by the Lockheed Aircraft Corporation.

Engineering Loft Photographic System:

All structure and sheet metal parts are sketched freehand in order to determine the basic designs. These freehand sketches with the necessary information are turned over to the loftsman, who by using any one of several conventional loft methods, obtains mold line contours or the exact shape of the entire plane. This mold line information is turned over to the detail layout group in the form of full-size line work on specially processed metal. This metal having previously been processed with a special paint which gives a finish to the metal similar to tracing cloth or paper as far as being adaptable to pencil or ink lines, layout work.

At this stage of the development, the engineering work is practically identical to that of the past systems, whereby, draftsmen lay out complete three-views in the conventional manner with the one exception that all dimensions are eliminated. This is possible due to all the layouts being full-size, and methods by which this information is passed on to the Manufacturing Departments. See Fig. 9:1.

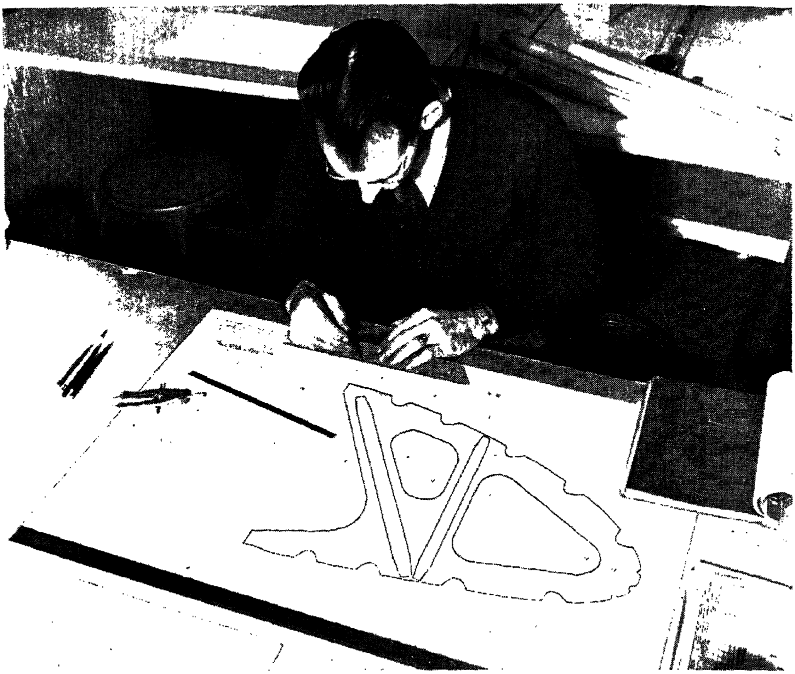


Fig. 9:1

After completion of the conventional three-view full-size layout, which has been checked and passed by the Design and Stress Groups, these layouts are then turned over to the men who have had the proper training and experience for the development of flat patterns or templates of all sheet metal structure which is shown in detail on these full-size layouts.

These various flat pattern developments are superimposed over the three-view layouts where it is possible to do so without causing confusion. If it is advisable a flat pattern may be developed to one side of the three-view on the same layout to eliminate possible confusion and to clarify the information which must be transmitted to the Fabrication Departments. Flat pattern developments clearly show in every detail the exact shape of each part which includes the stringer cutout, rivet or bolt location, and all information which is necessary for the Fabrication Department to have in order to pre-cut and drill the parts before they are

formed into the required shape. Also, all the tooling information is shown on these layouts, which will include the exact shape of the form block with all allowances made for spring back of the metal which occurs while the parts are being shaped. Also the location of pin holes or coordination holes is clearly shown and called out.

Upon completion of the flat pattern developments (See Fig. 9:2), the full-size drawings on metal are released to the Photo-

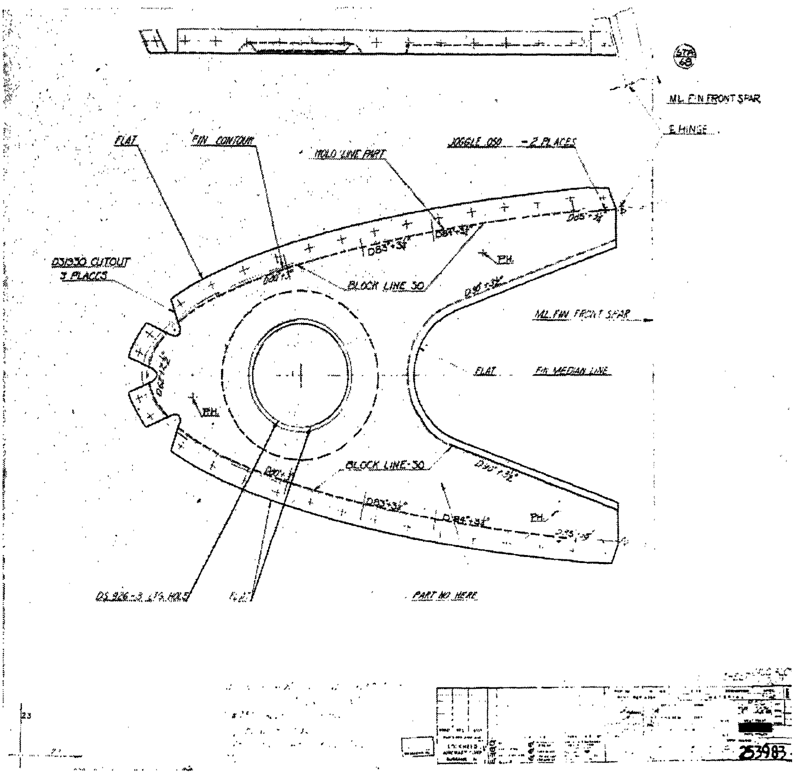


Fig. 9:2

graphic Department where with special cameras and equipment, a 14″ x 17″ glass negative is made. See Fig. 9:3. The original layout is then returned to the Engineering Department to be filed for future reference, and the 14″ x 17″ negative is used to make

five or six full size prints on metal, by using enlarging equipment.

The information obtainable in this form of a full-size exact scale reproduction of the original layout is very useful in a number of the departments throughout the plant. One or more copies

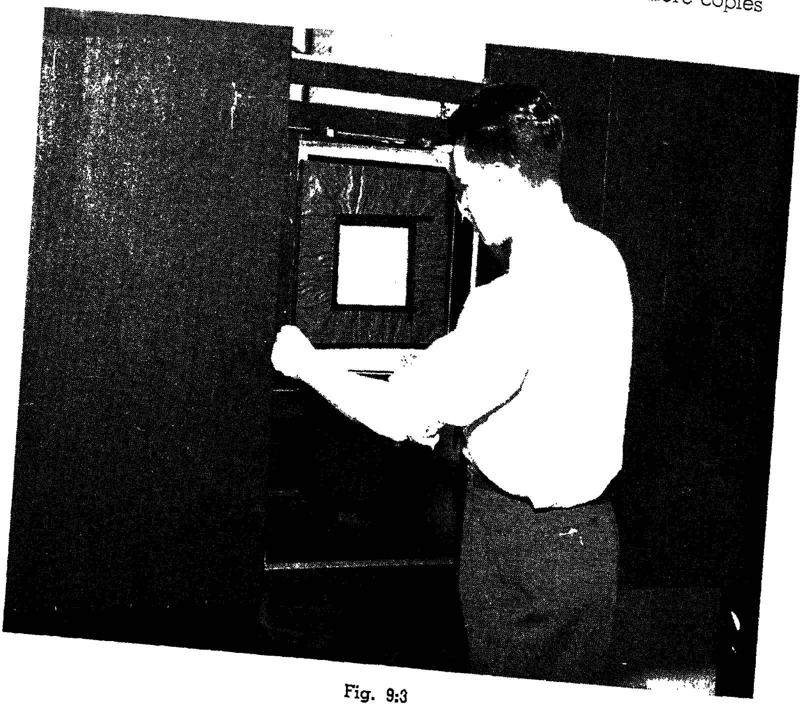


Fig. 9:3

go to the Template Department where all the necessary templates are made by cutting out the various views from the full-size prints. These templates consist of flat pattern templates (see Fig. 9:4), forming block or contour templates, and various other jig and tool templates. The Template Inspection Department receives one copy for reference in checking the workmanship on the templates which have been cut out and turned over to them by the Template Department. (See Fig. 9:6.) The Tool Design Department uses many of these full-size layouts to aid in the design and building of the necessary assembly and drill jigs.

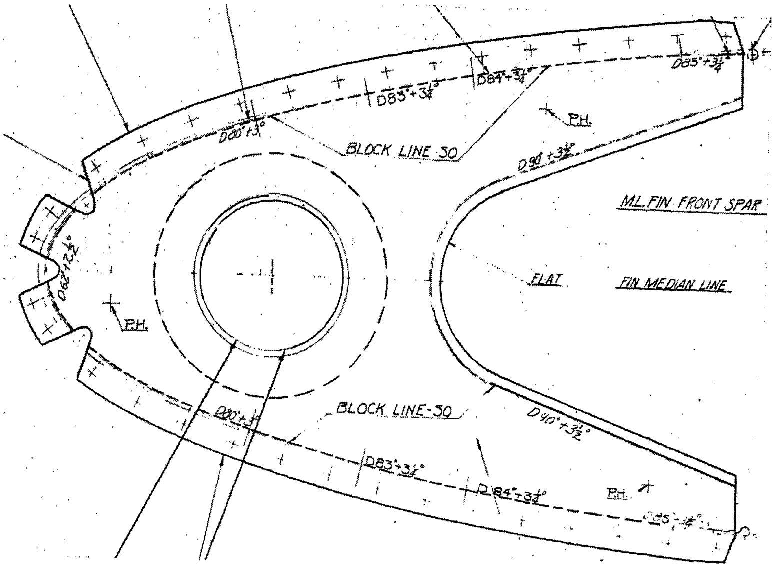


Fig. 9:4—Photographic Reproduction

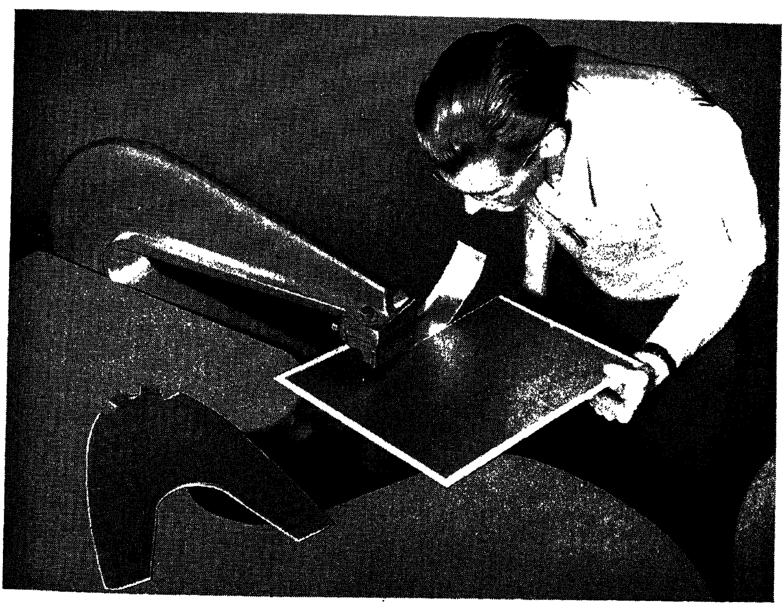


Fig. 9:5—Shearing Templates from Photographic Reproductions on Metal

It is possible to use this type of layout in many cases as a portion of the assembly jig by mounting hardened drill bushings in the proper location, or by having necessary location blocks mounted in various places to locate and hold the completed parts while

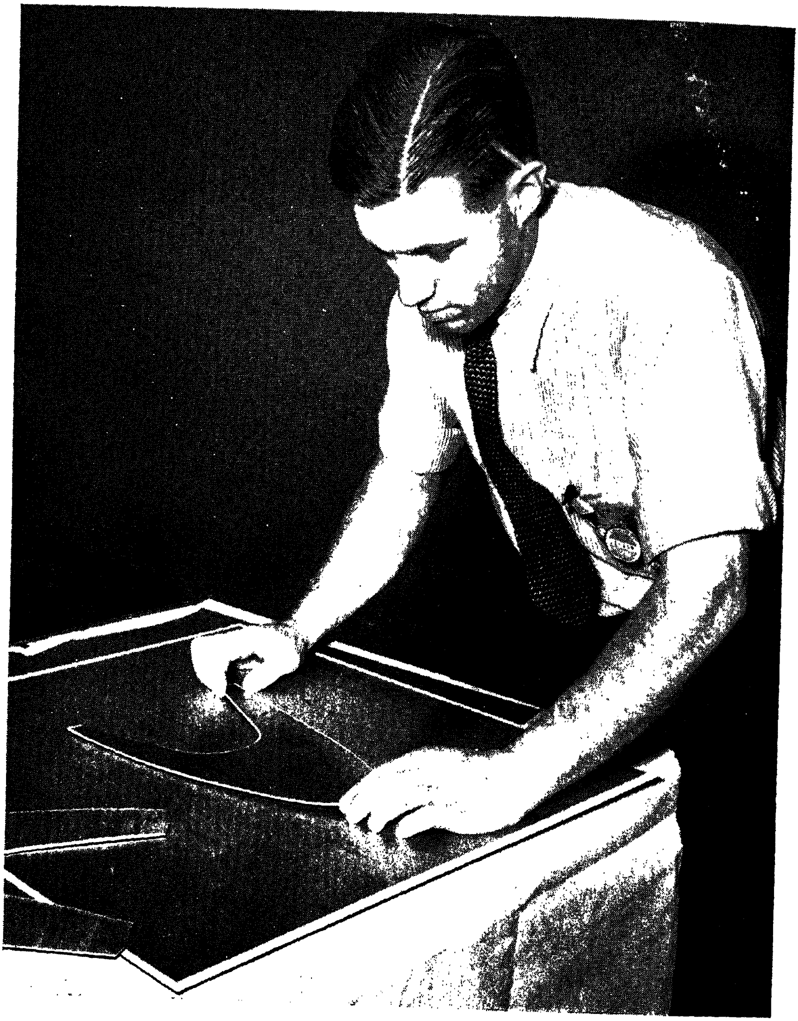


Fig. 9:6

they are being assembled and put together with either rivets, bolts, or by the spot welding operation.

Finished Parts Inspection Groups find these exact full-size layouts very useful in checking formed and fabricated parts. Fig. 9:7. Considerable time is saved by this method of visual inspection when the finished parts are checked to a line in comparison with the time necessary for measuring the parts to each individual dimension. Of course, in this case, the dimensions being eliminated from the layout, it becomes absolutely necessary for the

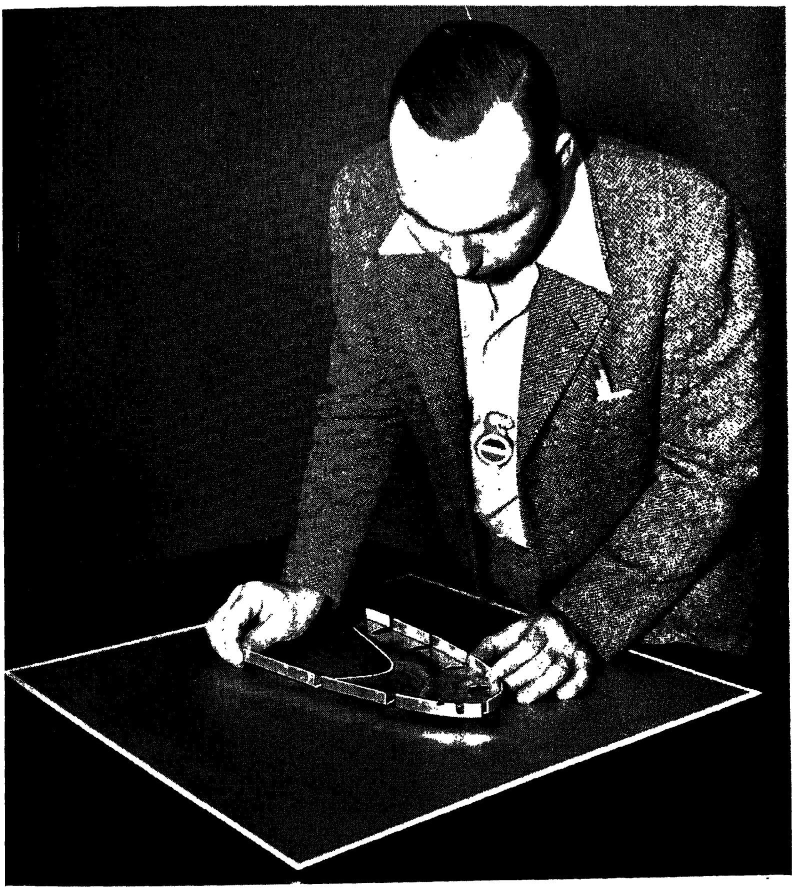


Fig. 9:7

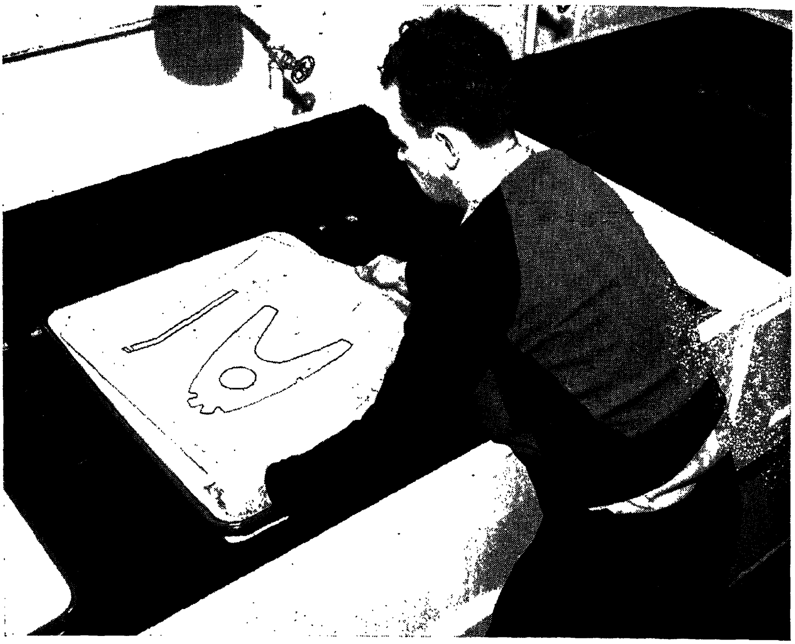


Fig. 9:8—Developing Tracing, Reproduced from Negative

inspection or the checking of parts to be done by this quicker and more up-to-date method.

It has been found that considerable time is saved by not dimensioning the various detail parts on the layout. This also eliminates numerous changes on layouts which originate from the wrong dimensions being placed on them, due to the fact that either the dimension was originally scaled improperly or in some cases due to errors in the scaling (which are multiplied by scaling $1/4$ to $1/2$ size layouts).

In conjunction with this type of layout, which is furnished to the shop for its information, numerous full-size interference layouts are made on the loft floor by the various groups, in order to determine interferences and the correct relationship of various parts to each other.

For example: A complete three-view of an engine installation layout is made full-size on the loft floor, showing in detail the motor in relation to all the necessary structure, plumbing and

wiring. In some cases it will be advisable to use different colored pencils to make this type of layout. If and when the fuel lines are laid out with a red pencil, the oil lines with a green pencil, and electrical lines with a purple or some other color, etc., it is

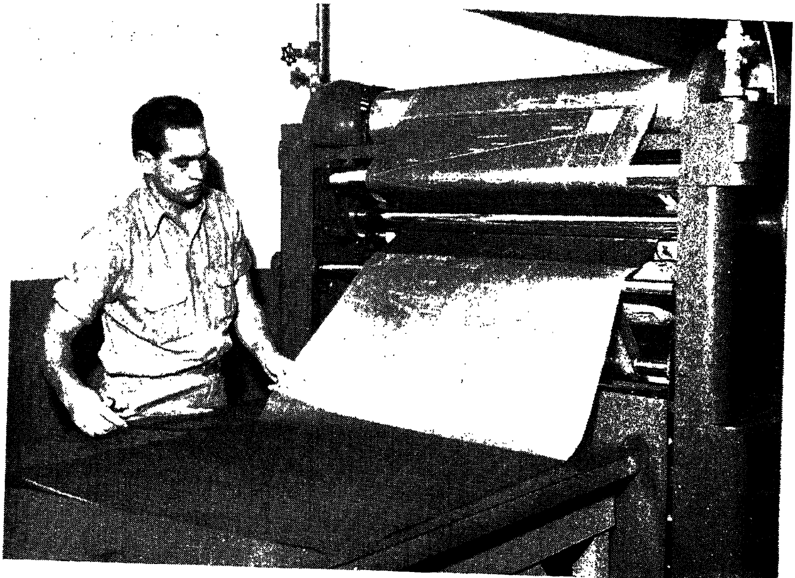


Fig. 9:9—Blueprints being made from Photo-Reproduced Tracing

possible by the use of lights and filters to take photographs of either the entire installation or any separate layout which has been done in the various colors. Then separate prints can be made of fuel lines, oil lines, or electrical installations, without the usual duplication of effort by the Engineer.

This type of interference layout is readily adaptable to numerous assemblies throughout the entire airplane, such as landing gear installation, wing and fuselage, etc. It is not necessary to print this type of layout full-size on metal, as this information is passed on to the shop in the form of blueprints. The blueprints are made from a tracing which has been printed in much the same manner as the full-size layouts on metal, simply by using sensitized tracing paper in the place of metal in the enlarging equipment.

It is advisable in many cases to make the tracings either 1/4 or 1/2 size where this information is more in the form of a picture of an assembly and will not be needed to obtain dimensions. This proper reduction is made on the tracing by the enlarging equipment.

The conventional method of making blueprints is followed (see Fig. 9:9) which makes it possible to issue information in this form to various groups within the organization where the full-size metal layout is not needed or would not be convenient for them to handle due to the weight and space involved in observing or filing this information.

The original tool planning groups use these 1/4 or 1/2 size blueprints for their preliminary design and planning; also the Production and Material Control Groups use engineering information issued in this form.

Numerous shrink or expanded contours and templates are required in the Plaster and Pattern Departments. This is accomplished by simply placing the original negative in the enlarging machine where the image is "blown up" to the proper shrink scale and printed on metal. These shrink contours are then cut out and turned over to the proper department where they either become part of the shrink mock-up or are used as tools to make up the necessary patterns.

CHAPTER X

TRADE ETHICS AND SAFETY PRECAUTIONS

It is highly important that you as a student maintain a normal physical condition, give ample consideration to personal attitude and working habits relative to your future occupation. Make it a point to cooperate with those around you and always be willing to help someone else if by so doing your employer will be benefited.

The following general requirements apply to persons seeking employment as a template maker or factory mechanic.

1. You should have a high school education or its equivalent.
2. Have with you your birth certificate or an equivalent statement from an attending doctor or other responsible person who can testify as to the time and place of birth. American Citizenship is required in all military work.
3. Be in normal or average physical and mental condition.
4. Be of the white race (exceptions made in a few rare cases).
5. Age limits are 18 to 30 years for unskilled or semi-skilled persons.
6. Ability—if the student has conscientiously applied himself to this text, has a thorough understanding of the subject matter in it, and is also able to apply his knowledge in a practical manner, he should be able to meet the minimum ability requirements of the aviation industry for template layout work.

As an employee you should first of all realize that your job is important and that you must apply yourself to all details in a thorough workmanlike manner. Following is a general list of some things you should conscientiously study and apply to your job.

1. Do not neglect to continue your studies; always be preparing for something better.
2. Keep yourself and your clothes neat and clean.
3. Keep your tools, your bench and your portion of the shop clean and neat.
4. Be on time for work and do not try to rush when it is time to quit for the day.
5. Always try to keep busy and give your employer a good day's work. If slack periods of time occur occasionally and

the leadman has nothing for you to do, then try to see what you can do to clean up your bench, or work out something that may save time or labor on future jobs, etc.

6. Study all blueprints and job orders carefully before starting on the actual work.
7. Do not borrow tools. Make it a point to own, at least, the minimum tools required by most companies. A good workman uses and cares for company tools as though they were his own.

When on the job you should conduct yourself in a gentlemanly manner and avoid rowdiness or horseplay at all times. Study company conduct regulations and especially abide by the following general rules.

1. Smoking is prohibited at all times except in some cases where specific areas are designated.
2. Do not loiter in the wash rooms or toilets during working hours.
3. Do not use or bring intoxicating liquor onto company property.
4. Do not do personal work on company machinery, or company time.
5. Do not engage in gambling in any form during working hours.
6. Last but not least watch your credit ratings and unpaid bills; most companies do not recognize wage or salary garnishees. A garnishee may result in the loss of your job.

SAFETY

Safety precautions are a very important part of the workman's duties. Each manufacturer has a well formulated set of rules designed to make the job safe.

Listed below are precautions especially pertaining to the template maker.

Always wear goggles while using or watching the use of the grinder, sander, band-saw, spot welder or any operations where flying particles might injure the eyes.

Never lift or attempt to lift any weight beyond your capacity. Always have sufficient help. When you do lift, keep the back nearly vertical, bend the knees and use the thigh muscles instead of the back muscles.

Do not carry on a conversation while operating a power tool. Keep your eyes and your mind on your work.

Never attempt to adjust, clean or oil a machine until you have turned off the power and the machine has come to a **dead stop.**

Do not use a rag to hold anything being ground or drilled.

Never use any power machinery unless all safety guards are in place.

When grinding see that the rest is secure and set close to the wheel.

Never grind anything on the side of the wheel; use the face only.

Be sure that drill is securely fastened in chuck and chuck wrench is removed before power is turned on.

Clamp small work firmly to table when using the drill press.

Don't use your hand as a brake to stop drill press.

Throw all oily waste or rags into metal containers provided for that purpose. Do not throw papers, metal shavings, scrap or glass into waste cans for oil rags. Do not throw metal shavings or metal scraps into waste paper containers.

Keep floors free of tripping or slipping hazards such as extension cords or pools of oil.

Keep sharp tools out of pockets.

The wearing of rings, neckties or loose clothing while working at power machines is to be avoided.

Soldering irons should always be placed so that you or fellow employees will not be inadvertantly burned.

All sharp edged tools must be used so that the cut is away from the body.

Never use a file without a handle.

Never use defective tools, such as a hammer with a loose head.

Don't use chisels, punches, etc., which have mushroomed heads.

Put sharp tools away when not in use.

Use a brush instead of your hand to clean off table tops, drill press, etc.

Keep gasoline and paint thinner in safe containers and away from spot-welder, soldering iron, etc.

When cutting sheet metal, handle the jagged scraps with care and place them in the proper container.

Remove burrs or wire edge from edges of metal after cutting or filing.

Use hand pads when carrying sheets of metal.

Don't leave templates or material extending over edges of table top.

If metal must extend into aisle while cutting or filing, see to it that the protruding sections are well padded.

Keep all machinery guards in place and any defective equipment should be reported to your foreman.

Accidents

Accidents are painful to you and costly to both you and the company for which you work. All accidents should be reported immediately to your foreman and the first aid department.

Accidents can be caused by running or crowding and other rowdiness or so called horseplay.

APPENDIX

GLOSSARY*

— A —

ACUTE ANGLE: An included angle of less than 90°.

ALCLAD: The registered trade mark used by the Aluminum Company of American to identify a group of high strength sheet aluminum alloys clad with a covering of high purity aluminum.

ARBOR & DATO SAW: A power saw having a shaft or bar for holding cutting tools.

— B —

BAND SAW: A saw in the form of an endless steel saw blade running over large diameter pulleys. The saw may be either a wood or a metal cutting saw.

BEND ALLOWANCE: The amount of sheet metal required to make a bend over a specific radius. The inside radius is used in aircraft work. It is the amount of metal required from the start of the bend to the end of the bend. It is based on the thickness of the metal, the type of metal used, the radius of bend involved, and the degree of bend. It is estimated from bend allowance charts which are derived from an empirical formula.

BENT UP ANGLE: The angle through which a part is bent up from the flat position.

BEVEL CURVE: Tangent heights laid out in the form of a polar graph for determining flange angles of bulkheads from a body plan view.

BEVEL STICKS: Graduated measuring pieces for determining flange angles of bulkheads from a body plan view.

BLANK: A sheet metal part after it has been blanked out by a die or cut out by hand, etc. It is considered to be a blank as long as there are no forming operations upon it.

BODY PLAN: A view looking forward along the length of a body and showing contours of various cross sections nested inside one another.

BODY STEEL: A type of low carbon sheet steel used in making automobile bodies.

— C —

CONCAVE: A surface which is hollow or curved inward.

CONVEX: A surface which is the opposite of a concave surface or curved outward.

— D —

DEVELOPED WIDTH OR LENGTH: The true or exact width or length of a part or section before it has been broken up (bent up) as in bending flanges or bending a part into a U shaped section.

DEVELOPMENT: Determining the dimensions and contours of templates.

DIE: A tool, the purpose of which is to impart any desired shape or impress any desired form or design on metals or materials. On those dies which shear a part out of the stock sheet or form it from the flat sheet, the die is the female portion which the punch enters to perform the required work.

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*Many of the words and definitions given in this glossary are reprinted from *"Baughman's Aviation Dictionary and Reference Guide—Aero-Thesaurus."*

— D — (Continued)

DRILL GUIDES: Hardened steel guides which are used as an aid for accurately drilling holes at specific locations.

DRILL JIG: A jig which holds parts or units of a structure in the proper position and location for drilling holes. In most cases a drill jig is so designed that the holes must be drilled to the required size, and properly coordinated with other mating parts.

DROP HAMMER: A large, heavy hammer used to produce certain types of work requiring complicated or elaborate forming, drawing or multiple bending of sheet stock. Matched dies (of zinc and lead alloy) are necessary, making the process economical only for standard production parts. The drop hammer is generally the male portion of a forming die, which is raised by a rope running over a power driven drum and allowed to drop freely into, or onto, the matching portion of the die. Deep draws are possible by this method of bumping. Typical examples of drop hammer work are: Inter-cylinder baffles, tank shells, fairing, wing corrugation, induction systems, etc. Materials from which drop-hammer parts are made for aircraft are: (1) Aluminum 2S½H, 3SO; (2) Alclad 17SO and 24SO; (3) Steel, extra deep drawing steel; Stainless steel, and Inconel.

DUCKS: Weights of various sizes and shapes and especially used to hold splines in position. See Fig. 7:8.

DUPLICATING PUNCH: A center punch used to transfer locations of centers, bend marks, etc., from the template to a part or a jig. The punch has a straight shank which fits accurately into a hole (preferably a small hole, #40 or #50) in the template and a small point just long enough to lightly mark the center location.

EMPIRICAL FORMULA: Any formula which has been constructed or built up from working experiences, shop practices, etc., rather than from theory and mathematics, e.g., the "empirical formula" in common use for the determination of bend allowances in aircraft sheet metal work has been formed by the experience gained from a large number of tests by bending various thicknesses of metal through many angles.

ENGINEERING BLUEPRINTS: Blue prints of drawings which have been made by the engineering department. They show all engineering data and are the basis from which other special drawings are made.

— F —

FAIRING: An auxiliary member or structure whose primary function is to reduce head resistance or drag of the part to which it is fitted.

FLANGE: Any web stiffening portion of I-beam sections, channel sections, cap strips on wing ribs, or spars, etc.

FORM BLOCK: A block (die) made of masonite, wood, zinc, steel or aluminum over which sheet metal is formed by any of the various methods of forming sheet metal. A form block is used to bend flanges, put in joggles, form stiffening beads, etc.

FRAMES: The lateral members of monocoque and semi-monocoque structures which give form and maintain the shape of the structure.

— G —

GALVANIZED IRON: A name applied to iron or steel sheets coated with zinc applied by dipping in a bath of molten metal. The coating of zinc protects the iron core from corrosion.

—H—

HYDRAULIC PRESS: A pressure press operated by Hydraulics. Large hydraulic presses are used in aircraft production for power forming sheet metal parts. The work is done either by using matched male and female dies of wood, masonite, steel or zinc, or by using a die and thick, heavy rubber blankets or pads which form the metal around or into the die.

—I—

INDEXING PINS: Pins used to align or locate parts in relation to each other or relative parts. One use of indexing pins is their use in a form block in conjunction with the pin holes in a template or part which is to be formed.

INSIDE MOLD LINE: A line formed by the intersecting of two planes (flat surfaces), when dealing with the inside surfaces of the legs of the angle.

—J—

J CHART: A special bend allowance and development chart. **See page 276.**

JOGGLE: sht. metl.: Offsetting a small portion of a metal part (an angle or a flange, etc.) so that the joggled part will clear (pass over) other parts.

—K—

KIRKSITE: A zinc alloy commonly used to make drop hammer and hydro press dies.

—L—

LIGHTENING HOLES, in sheet metal parts: Large holes in many sheet metal aircraft parts where the metal has been removed because the metal in that specific location was not doing any useful work and its removal lessened the weight with no decrease in the structural strength of the part; such holes are usually flanged or stiffened at their edges.

—M—

MOLD LINE (ML): A line formed by the intersecting of two planes (flat surfaces). In the case of an angle where the bend is a radius the mold line will be in space at the point where the outside surfaces of the legs of the angle would meet if they were extended. This mold line is called the Outside Mold Line and it is an Inside Mold Line when dealing with the inside surfaces of the legs of the angle.

—N—

NEST: A guide for a die punch or a condition existing when two formed parts are made to fit very close together, i.e., the parts are said to "nest together."

NIBBLING MACHINE: A machine which incorporates a die and punch which operates at high speed and is used to cut out metal parts, especially those parts which are of any intricate shape. The nibbler was formerly extensively used but of late years other machines have been introduced which do similar work.

—O—

OBTUSE ANGLE: An included angle greater than 90°.

OFFSETS: (dimensioning): A method of dimensioning tapers and angles by means of dimension lines which show the amount of departure of the angle or edge of the part from the base line.

OUTSIDE MOLD LINE: A line formed by the intersecting of two planes (flat surfaces) where the bend is a radius and the mold line is in space at the point where the outside surfaces of the legs of the angle would meet if extended.

— P —

PANTOGRAPH: A duplicating device which will trace the outline of a given object to any desired scale (larger or smaller).

PATTERN: A model for making the mold into which molten metal is poured to form a casting. Also any flat model of a part which can be used as an aid in reproducing other parts.

PEIN: To force or shape the edge of a metal part. Also the name applied to a machinist hammer having one ball or pein surface.

PILOT HOLE: Locating hole or a small hole used to guide a larger drill.

PIN HOLE: A hole or holes located accurately in blanks, to enable them to be placed on the locating pins which are inset into the form block. These holes are also generally located on the template.

PLASTER MOCK-UP: A hollow full sized model or imitation of an object made of plaster of paris. Built upon a framework of wood and wire.

PLATEN: A flat bed or table incorporated in a machine or machine tool for the purpose of supporting and anchoring the work while it is undergoing any process of fabrication.

PUNCH, of a die: The male portion of a die. A metal part is sheared out of a stock sheet because the punch forces the metal through the die and a shearing action exists between the edges of the punch and the die. Also a punch is the male portion of a forming or drawing die.

— R —

RADIAL DRILL: A drill having a moveable head arranged so as to be moved over a large area by the operator and positioned over various holes which are to be drilled.

RELIEF RADIUS: Small holes located at the intersection of two bends. Their purpose is to remove excessive metal at the intersection.

RIGHT ANGLE: An angle equal to 90°.

— S —

SCRATCH COAT: A rough undercoat of plaster used when making a plaster mock-up.

SCRIBE: A metal marking device.

SCRIEVE BOARD: A sheet of wood or metal upon which the line results of various lofting operations are recorded in the form of contours and other measurable lines placed on or cut into the board.

SHEET METAL: Metal of any thickness up to one-eighth inch. Metal thicker than one-eighth is termed plate.

SKIN: The outer covering of monocoque or semi-monocoque structures.

SPLINE: A flexible strip of some suitable material such as wood, metal, pyralin, plexiglass, celluloid, etc., which can be curved to form faired lines.

SPRING BACK, metal: The angular amount by which a tempered or semi-hardened metal springs back after it has been bent through some specific angle. It must be allowed for when making bends with the power brake or when making form blocks and also when making form dies or drawing dies.

STERIC ACID: Steric acid is a compound often used to coat portions of the frame of a plaster mock-up to prevent the plaster of paris from sticking to it.

STRINGER: An internal longitudinal support for the skin in a monocoque fuselage, also used in the wings as a skin stiffener.

— T —

TANGENT HEIGHT: The length of the side of a right triangle which is opposite the acute angle being considered.

TERNE PLATE: Ordinary soft steel sheet which has a surface coating of an alloy of lead (80%) and tin (20%). Terne plate is sometimes called tin plate.

TRANSFER PUNCH: See Duplicating Punch.

TRIAL FILLETS: Temporary fillets, usually rather rough and unfinished.

BEND ALLOWANCES FOR U.S.S. GAGE FERROUS SHEET

R \ T	.028	.031	.034	.038	.050	.056	.063	.070	.078	.094	.109	.125	5/32	3/16	1/4	5/16
1/32	.00076	.00079	.00081	.00084	.00093	.00098										
1/16	.00131	.00133	.00136	.00138	.00148	.00153	.00158	.00164								
3/32	.00185	.00188	.00190	.00193	.00202	.00207	.00212	.00218	.00224							
1/8	.00240	.00242	.00245	.00247	.00257	.00262	.00267	.00273	.00279	.00291						
5/32	.00294	.00297	.00299	.00302	.00311	.00316	.00321	.00327	.00333	.00346	.00358					
3/16	.00349	.00351	.00354	.00356	.00366	.00371	.00376	.00382	.00388	.00400	.00412	.00424				
7/32	.00403	.00406	.00408	.00411	.00420	.00425	.00430	.00436	.00442	.00454	.00467	.00479				
1/4	.00458	.00460	.00463	.00465	.00475	.00480	.00485	.00491	.00497	.00509	.00521	.00533	.00558			
9/32	.00512	.00514	.00517	.00519	.00529	.00534	.00539	.00545	.00551	.00563	.00576	.00588	.00612			
5/16	.00567	.00569	.00572	.00574	.00584	.00589	.00593	.00600	.00606	.00618	.00630	.00642	.00667	.00691		
11/32	.00621	.00624	.00626	.00628	.00638	.00643	.00648	.00654	.00660	.00672	.00684	.00697	.00721	.00745		
3/8	.00676	.00678	.00680	.00683	.00693	.00698	.00702	.00708	.00715	.00727	.00739	.00751	.00776	.00800	.00849	
13/32	.00730	.00733	.00735	.00737	.00747	.00752	.00757	.00763	.00769	.00781	.00793	.00806	.00830	.00854	.00903	
7/16	.00784	.00787	.00789	.00792	.00802	.00806	.00811	.00817	.00823	.00836	.00848	.00860	.00884	.00909	.00958	.01006
15/32	.00839	.00841	.00844	.00846	.00856	.00861	.00866	.00872	.00878	.00890	.00902	.00915	.00939	.00963	.01012	.01061
1/2	.00893	.00896	.00898	.00901	.00910	.00915	.00920	.00926	.00932	.00945	.00957	.00969	.00993	.01018	.01067	.01115
17/32	.00948	.00950	.00953	.00955	.00965	.00970	.00975	.00981	.00987	.00999	.01011	.01023	.01048	.01072	.01121	.01170
9/16	.01002	.01005	.01007	.01010	.01019	.01024	.01029	.01035	.01041	.01054	.01066	.01078	.01102	.01127	.01175	.01224
19/32	.01057	.01059	.01062	.01064	.01074	.01079	.01084	.01090	.01096	.01108	.01120	.01132	.01157	.01181	.01230	.01279
5/8	.01111	.01114	.01116	.01119	.01128	.01133	.01138	.01144	.01150	.01163	.01175	.01187	.01211	.01236	.01284	.01333
21/32	.01166	.01168	.01171	.01173	.01183	.01188	.01193	.01199	.01205	.01217	.01229	.01241	.01266	.01290	.01339	.01388
11/16	.01220	.01223	.01225	.01228	.01237	.01242	.01247	.01253	.01259	.01271	.01284	.01296	.01320	.01345	.01393	.01442
23/32	.01274	.01277	.01280	.01282	.01292	.01297	.01302	.01308	.01314	.01326	.01338	.01350	.01374	.01399	.01448	.01497
3/4	.01329	.01332	.01334	.01337	.01346	.01351	.01356	.01362	.01368	.01380	.01393	.01405	.01429	.01454	.01502	.01551
25/32	.01384	.01386	.01389	.01391	.01401	.01406	.01410	.01417	.01423	.01435	.01448	.01459	.01484	.01508	.01557	.01605
13/16	.01438	.01441	.01443	.01445	.01455	.01460	.01465	.01471	.01477	.01489	.01502	.01514	.01538	.01562	.01611	.01660
27/32	.01493	.01495	.01497	.01500	.01510	.01515	.01519	.01525	.01532	.01544	.01556	.01568	.01593	.01617	.01666	.01714
7/8	.01547	.01550	.01552	.01554	.01564	.01569	.01574	.01580	.01586	.01598	.01610	.01623	.01647	.01671	.01720	.01769
29/32	.01602	.01604	.01606	.01609	.01619	.01624	.01628	.01634	.01641	.01653	.01665	.01677	.01701	.01726	.01775	.01823
15/16	.01656	.01658	.01661	.01663	.01673	.01678	.01683	.01689	.01695	.01707	.01719	.01732	.01756	.01780	.01829	.01878
31/32	.01710	.01713	.01715	.01718	.01728	.01732	.01737	.01743	.01749	.01762	.01774	.01786	.01810	.01835	.01884	.01932
1	.01765	.01767	.01770	.01772	.01782	.01787	.01792	.01798	.01804	.01816	.01828	.01841	.01865	.01889	.01938	.01987

(A) Values given are based on the empirical formula (.01743R +.0078T) X No. of degrees. R = inside radius of bend and T = thickness of sheet in inches.
(B) Values given are Bend Allowance (B.A.) for 1° of the given radii X of the thickness of the metal.
(C) Values omitted from table are not to be used as the bends are too sharp for satisfactory production.

BEND ALLOWANCES FOR B. & S. GAGE NON-FERROUS SHEET

R \ T	.016	.020	.022	.025	.028	.032	.040	.045	.051	.064	.072	.081	.091	.128	5/32	3/16
1/32	.00067	.00070	.00072	.00074	.00077	.00079										
1/16	.00121	.00125	.00126	.00129	.00131	.00135	.00140	.00144	.00149	.00159	.00165					
3/32	.00176	.00179	.00180	.00183	.00186	.00188	.00195	.00199	.00203	.00213	.00220	.00226	.00234			
1/8	.00230	.00234	.00235	.00238	.00240	.00243	.00249	.00253	.00258	.00268	.00274	.00281	.00289	.00317		
5/32	.00285	.00288	.00290	.00292	.00295	.00297	.00304	.00308	.00312	.00322	.00328	.00335	.00343	.00372	.00394	
3/16	.00339	.00342	.00344	.00347	.00349	.00352	.00358	.00362	.00367	.00377	.00383	.00390	.00398	.00426	.00449	.00473
7/32	.00394	.00397	.00398	.00401	.00403	.00406	.00412	.00417	.00421	.00431	.00437	.00444	.00452	.00481	.00503	.00528
1/4	.00448	.00451	.00454	.00456	.00458	.00461	.00467	.00471	.00476	.00486	.00492	.00499	.00507	.00535	.00558	.00582
9/32	.00503	.00506	.00507	.00510	.00512	.00515	.00521	.00526	.00530	.00540	.00546	.00553	.00561	.00590	.00612	.00636
5/16	.00557	.00560	.00562	.00564	.00567	.00570	.00576	.00580	.00584	.00595	.00601	.00608	.00616	.00644	.00667	.00691
11/32	.00612	.00615	.00616	.00619	.00621	.00624	.00630	.00634	.00639	.00649	.00655	.00662	.00670	.00699	.00721	.00745 24SO
3/8	.00666	.00669	.00671	.00673	.00676	.00679	.00685	.00689	.00693	.00704	.00710	.00717	.00725	.00753	.00776	.00800
13/32	.00721	.00724	.00725	.00728	.00730	.00733	.00739	.00743	.00748	.00758	.00764	.00771	.00779	.00808	.00830	.00854
7/16	.00775	.00778	.00780	.00782	.00785	.00787	.00794	.00798	.00802	.00812	.00819	.00826	.00834	.00862	.00884	.00909
15/32	.00829	.00833	.00834	.00837	.00839	.00842	.00848	.00852	.00857	.00867	.00873	.00880	.00888	.00917	.00939	.00963
1/2	.00884	.00887	.00889	.00891	.00894	.00896	.00903	.00907	.00911	.00921	.00928	.00935	.00943	.00971	.00993	.01018
17/32	.00938	.00942	.00943	.00946	.00948	.00951	.00957	.00961	.00966	.00976	.00982	.00989	.00997	.01025	.01048	.01072
9/16	.00993	.00996	.00998	.01000	.01002	.01005	.01012	.01016	.01020	.01030	.01037	.01043	.01051	.01080	.01102	.01127
19/32	.01047	.01051	.01051	.01055	.01057	.01058	.01065	.01070	.01073	.01083	.01091	.01098	.01105	.01133	.01157	.01181 17ST
5/8	.01102	.01105	.01107	.01109	.01112	.01114	.01121	.01125	.01129	.01139	.01146	.01152	.01160	.01189	.01211	.01236
21/32	.01156	.01160	.01161	.01164	.01166	.01170	.01175	.01179	.01183	.01193	.01200	.01207	.01214	.01245	.01266	.01290
11/16	.01211	.01214	.01216	.01218	.01220	.01223	.01230	.01234	.01238	.01248	.01254	.01261	.01269	.01298	.01320	.01345
23/32	.01265	.01268	.01269	.01273	.01275	.01276	.01283	.01288	.01291	.01301	.01309	.01316	.01322	.01351	.01374	.01399
3/4	.01320	.01323	.01324	.01327	.01329	.01332	.01338	.01343	.01347	.01357	.01363	.01370	.01378	.01407	.01429	.01454
25/32	.01374	.01378	.01378	.01381	.01384	.01386	.01392	.01397	.01401	.01411	.01418	.01425	.01432	.01461	.01484	.01508
13/16	.01429	.01432	.01433	.01436	.01438	.01441	.01447	.01451	.01456	.01466	.01472	.01479	.01487	.01516	.01538	.01562
27/32	.01483	.01486	.01487	.01490	.01493	.01494	.01501	.01506	.01509	.01519	.01527	.01534	.01540	.01569	.01593	.01617 24ST
7/8	.01538	.01541	.01542	.01545	.01547	.01550	.01556	.01560	.01565	.01575	.01581	.01588	.01596	.01625	.01647	.01671
29/32	.01592	.01595	.01596	.01599	.01602	.01604	.01616	.01615	.01619	.01629	.01636	.01643	.01650	.01679	.01701	.01726
15/16	.01646	.01650	.01651	.01654	.01656	01659	.01665	.01669	.01674	.01684	.01690	.01697	.01705	.01734	.01756	.01780 24SRT
31/32	.01701	.01704	.01705	.01708	.01711	.01712	.01718	.01724	.01727	.01737	.01745	.01752	.01758	.01787	.01810	.01835
1	.01755	.01759	.01760	.01763	.01765	.01768	.01774	.01778	.01783	.01793	.01799	.01806	.01814	.01843	.01865	.01889

(A) Values given are based on the empirical formula (.01743R + .0078T) times No. of degrees. R = inside radius of bend and T = thickness of sheet in inches.
(B) Values given are Bend Allowances (B.A.) for 1° of the given radii X the thickness of the metal.
(C) Values omitted from table are not to be used as the bends are too sharp for satisfactory production.
(D) All values on this page are O.K. for 17SO.
(E) Values below the line are to be used for 24SO, 17ST, 24ST and 24SRT as noted.

METAL BEND ALLOWANCE CHART FOR 90° (DURAL & STEEL)

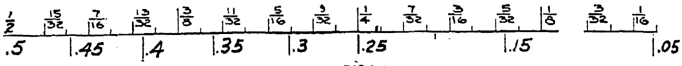
T / R	.020 .022	.023 .025	.028 .029	.031 .032	.036 .040	.050 .051	.063 .064	.081	.091 .094	.125 .129	.182	.187	.250	.258
1/32	.0648	.0657	.0648	.0711	.0774	.0846	.0936	.1053	.1125	.1386	.1764	.1800	.2241	.2304
1/16	.1134	.1152	.1179	.1215	.1260	.1341	.1431	.1548	.1620	.1881	.2259	.2295	.2736	.2790
3/32	.1620	.1647	.1665	.1692	.1755	.1827	.1917	.2034	.2106	.2367	.2745	.2781	.3222	.3285
1/8	.2115	.2133	.2160	.2187	.2241	.2322	.2412	.2529	.2601	.2853	.3240	.3276	.3717	.3771
5/32	.2610	.2620	.2646	.2673	.2736	.2808	.2898	.3015	.3087	.3348	.3726	.3762	.4203	.4257
3/16	.3098	.3114	.3141	.3160	.3233	.3303	.3393	.3510	.3582	.3834	.4221	.4257	.4698	.4752
7/32	.3582	.3609	.3627	.3654	.3700	.3789	.3879	.3996	.4068	.4329	.4707	.4743	.5194	.5238
1/4	.4086	.4095	.4122	.4149	.4203	.4284	.4374	.4500	.4563	.4815	.5202	.5238	.5679	.5733
9/32	.4563	.4590	.4608	.4635	.4629	.4770	.4860	.4977	.5049	.5310	.5688	.5724	.6165	.6219
5/16	.5058	.5076	.5103	.5130	.5194	.5258	.5355	.5472	.5544	.5796	.6183	.6219	.6660	.6714
11/32	.5544	.5571	.5580	.5616	.5670	.5751	.5841	.5958	.6030	.6291	.6669	.6705	.7146	.7200
3/8	.6039	.6057	.6075	.6111	.6165	.6237	.6330	.6453	.6525	.6777	.7164	.7200	.7641	.7695
13/32	.6525	.6552	.6570	.6597	.6651	.6732	.6822	.6939	.7011	.7272	.7650	.7686	.8127	.8181
7/16	.7020	.7038	.7056	.7083	.7146	.7218	.7308	.7434	.7506	.7758	.8136	.8172	.8622	.8676
15/32	.7506	.7524	.7551	.7578	.7632	.7713	.7803	.7677	.7992	.8253	.8631	.8667	.9108	.9162
1/2	.8001	.8019	.8037	.8064	.8127	.8199	.8289	.8415	.8487	.8739	.9117	.9153	.9603	.9657
17/32	.8487	.8505	.8532	.8559	.8613	.8694	.8811	.8901	.8973	.9225	.9612	.9648	1.0089	1.0143
9/16	.8982	.9000	.9018	.9045	.9108	.9180	.9270	.9396	.9459	.9720	1.0098	1.0134	1.0575	1.0638
19/32	.9459	.9486	.9495	.9522	.9585	.9657	.9747	.9882	.9945	1.0197	1.0593	1.0611	1.1070	1.1124
5/8	.9963	.9981	.9999	1.0026	1.0089	1.0161	1.0251	1.0368	1.0440	1.0701	1.1079	1.1115	1.1556	1.1619
21/32	1.0449	1.0467	1.0494	1.0530	1.0575	1.0647	1.0737	1.0863	1.0926	1.1205	1.1574	1.1601	1.2015	1.2105
11/16	1.0944	1.0962	1.0980	1.1007	1.1070	1.1142	1.1232	1.1349	1.1421	1.1682	1.2060	1.2096	1.2537	1.2600
23/32	1.1421	1.1448	1.1457	1.1484	1.1547	1.1619	1.1709	1.1844	1.1896	1.2159	1.2555	1.2573	1.3032	1.3086
3/4	1.1916	1.1943	1.1961	1.1988	1.2042	1.2123	1.2213	1.2330	1.2402	1.2663	1.3050	1.3077	1.3518	1.3572
25/32	1.2402	1.2429	1.2447	1.2474	1.2528	1.2609	1.2699	1.2825	1.2888	1.3149	1.3536	1.3563	1.4013	1.4067
13/16	1.2897	1.2924	1.2942	1.2969	1.3023	1.3104	1.3194	1.3311	1.3383	1.3644	1.4022	1.4058	1.5499	1.4553
27/32	1.3383	1.3410	1.3419	1.3446	1.3509	1.3581	1.3671	1.3806	1.3860	1.4121	1.4508	1.4535	1.4994	1.5048
7/8	1.3878	1.3905	1.3932	1.3950	1.4004	1.4085	1.4175	1.4292	1.4364	1.4625	1.5003	1.5039	1.5489	1.5534
29/32	1.4364	1.4400	1.4409	1.4436	1.4490	1.4571	1.4661	1.4787	1.4850	1.5111	1.5489	1.5543	1.5975	1.6029
15/16	1.4859	1.4886	1.4895	1.4922	1.4985	1.5066	1.5156	1.5273	1.5345	1.5606	1.5984	1.6020	1.6461	1.6515
31/32	1.5345	1.5372	1.5381	1.5408	1.5462	1.5543	1.5633	1.5768	1.5822	1.6083	1.6470	1.6497	1.6911	1.7001
1	1.5840	1.5867	1.5885	1.5912	1.5966	1.6047	1.6137	1.6254	1.6326	1.6587	1.6965	1.7001	1.7442	1.7496

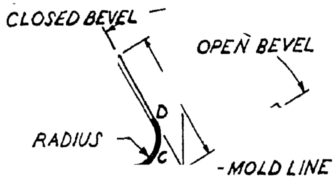
Legend: Minimum allowance below line ——— for hard dural. Minimum allowance below line: — — — — — — for soft dural and steel.

DECIMAL AND METRIC EQUIVALENTS OF PARTS OF AN INCH

Fractional Inches	Decimal Inches	Millimeters	Fractional Inches	Decimal Inches	Millimeters
1/64	.015625	0.39687	33/64	.515625	13.09692
1/32	.03125	0.79375	17/32	.53125	13.49380
3/64	.046875	1.19062	35/64	.546875	13.89067
1/16	.0625	1.58750	9/16	.5625	14.28755
5/64	.078125	1.98438	37/64	.578125	14.68443
3/32	.09375	2.38125	19/32	.59375	15.08130
7/64	.109375	2.77813	39/64	.609375	15.47818
1/8	.125	3.17501	5/8	.625	15.87506
9/64	.140625	3.57188	41/64	.640625	16.27193
5/32	.15625	3.96876	21/32	.65625	16.66881
11/64	.171875	4.36564	43/64	.671875	17.06569
3/16	.1875	4.76251	11/16	.6875	17.46256
13/64	.203125	5.15939	45/32	.703125	17.85944
7/32	.21875	5.55627	23/32	.71875	18.25632
15/64	.234375	5.95314	47/64	.734375	18.65319
1/4	.25	6.35002	3/4	.75	19.05007
17/64	.265625	6.74690	49/64	.765625	19.44695
9/32	.28125	7.14377	25/32	.78125	19.84382
19/64	.296875	7.54065	51/64	.796875	20.24070
5/16	.3125	7.93753	13/16	.8125	20.63758
21/64	.328125	8.33440	53/64	.828125	21.03445
11/32	.34375	8.73128	27/32	.84375	21.43133
23/64	.359375	9.12816	55/64	.859375	21.82821
3/8	.375	9.52503	7/8	.875	22.22508
25/64	.390625	9.92191	57/64	.890625	22.62196
13/32	.40625	10.31879	29/32	.90625	23.01884
27/64	.421875	10.71566	59/64	.921875	23.41571
7/16	.4375	11.11254	15/16	.9375	23.81259
29/64	.453125	11.50942	61/64	.953125	24.20947
15/32	.46875	11.90629	31/32	.96875	24.60634
31/64	.484375	12.30317	63/64	.984375	25.00322
1/2	.5	12.70005	1	1.00000	25.40010

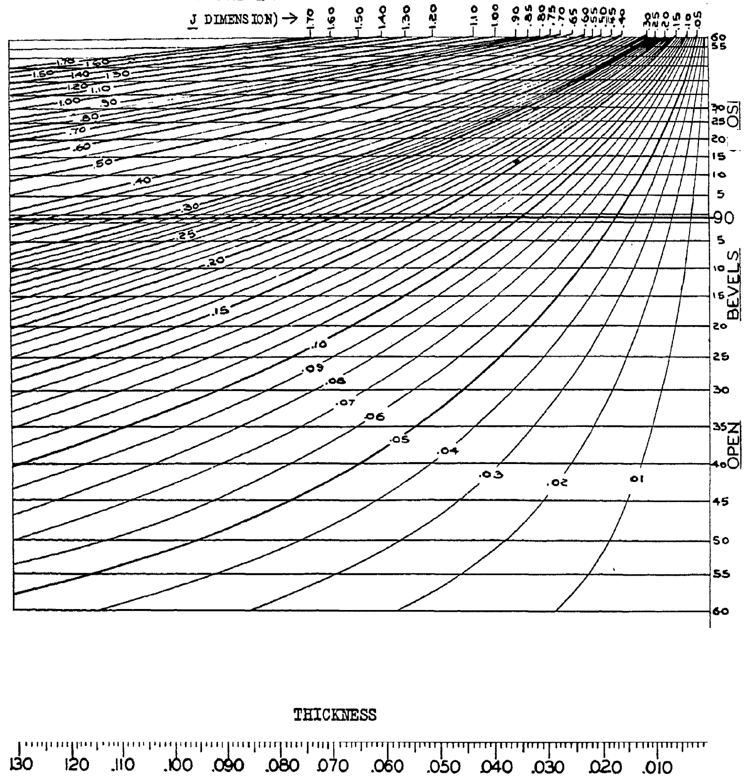
SET—BACK or "J" CHART





J is the amount of set back. It is equal to the difference in the length of the metal that would be required to form the angle DGE and the length of the metal in the arc C. It is the amount to be subtracted from the sum of the flange dimension.

The developed width of the flat strip from which the angle is formed is (A+B)-J.



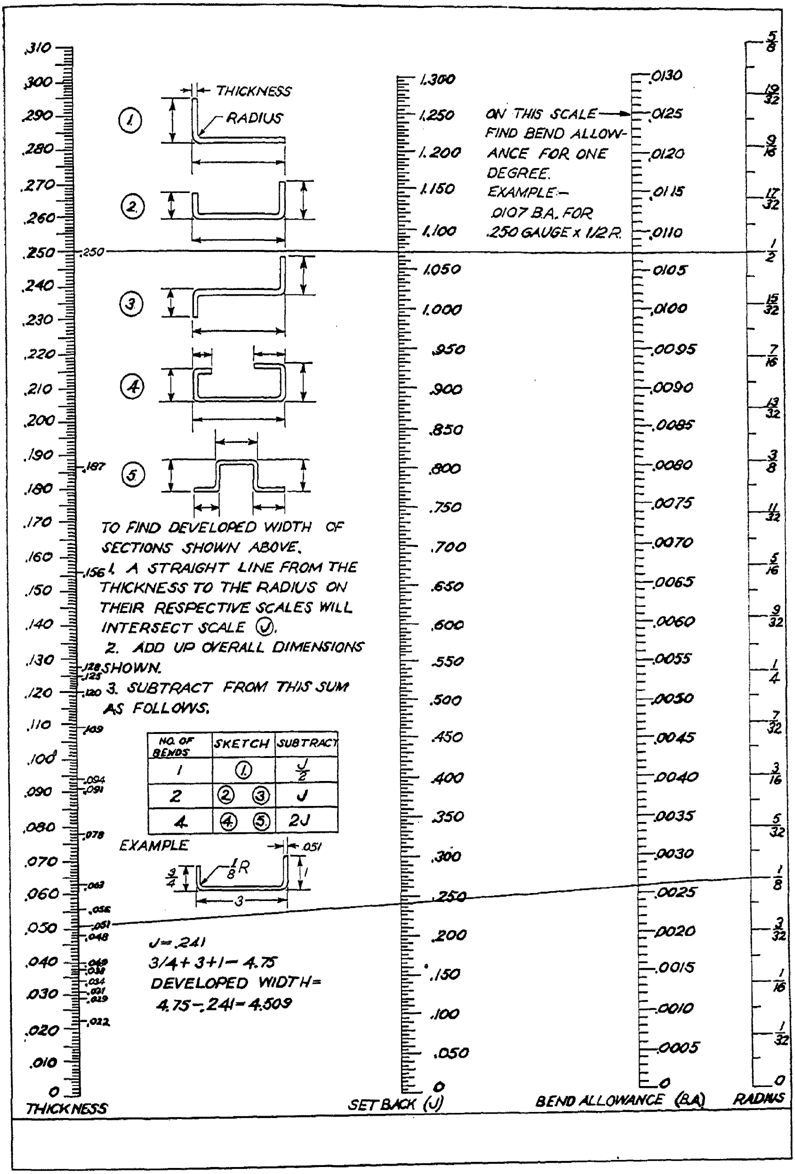
HOW TO USE SET-BACK CHART: (Example) Metal thickness .050 bent on a radius of 1/8" through a closed angle of 15°.

Lay a straight edge across the chart, connecting points of 1/8" radius and .050 metal thickness. Follow the line of 15° closed bevel over to its intersection with the straight edge and read .190. The amount of J nearest the intersection is the amount of set-back.

NOTE: A or B minus 1/2 J indicates the location of the center of the bend from the end of the metal.

Set-back is subtracted only once for each bend.

COMBINED SET BACK AND BEND ALLOWANCE CHART



DRILL SIZES

When specifying drilled holes give nominal drill size and decimal equivalent to three places.

SIZE	DECIMAL EQUIV.	SIZE	DECIMAL EQUIV.	SIZE	DECIMAL EQUIV.	SIZE	DECIMAL EQUIV.
80	.0135	7/64	.1094	17/64	.2656	49/64	.7656
79	.0145	35	.1100	H	.2660	25/32	.7812
1/64	.0156	34	.1110	I	.2720	51/64	.7968
78	.0160	33	.1130	J	.2770	13/16	.8125
77	.0180	32	.1160	K	.2810	53/64	.8281
76	.0200	31	.1200	9/32	.2812	27/32	.8437
75	.0210	1/8	.1250	L	.2900	55/64	.8593
74	.0225	30	.1285	M	.2950	7/8	.8750
73	.0240	29	.1360	19/64	.2969	57/64	.8906
72	.0250	28	.1405	N	.3020	29/32	.9062
71	.0260	9/64	.1406	5/16	.3125	59/64	.9218
70	.0280	27	.1440	O	.3160	15/16	.9375
69	.0292	26	.1470	P	.3230	61/64	.9531
68	.0310	25	.1495	21/64	.3281	31/32	.9687
1/32	.0313	24	.1520	Q	.3320	63/64	.9843
67	.0320	23	.1540	R	.3390	1	1.0000
66	.0330	5/32	.1562	11/32	.3437	1 1/64	1.0156
65	.0350	22	.1570	S	.3480	1 1/32	1.0312
64	.0360	21	.1590	T	.3580	1 3/64	1.0468
63	.0370	20	.1610	23/64	.3594	1 1/16	1.0625
62	.0380	19	.1660	U	.3680	1 5/64	1.0781
61	.0390	18	.1695	3/8	.3750	1 3/32	1.0937
60	.0400	11/64	.1719	V	.3770	1 7/64	1.1093
59	.0410	17	.1730	W	.3860	1 1/8	1.1250
58	.0420	16	.1770	25/64	.3906	1 9/64	1.1406
57	.0430	15	.1800	X	.3970	1 5/32	1.1562
56	.0465	14	.1820	Y	.4040	1 11/64	1.1718
3/64	.0469	13	.1840	13/32	.4062	1 3/16	1.1875
55	.0520	3/16	.1875	Z	.4130	1 13/64	1.2031
54	.0550	12	.1890	27/64	.4219	1 7/32	1.2187
53	.0595	11	.1910	7/16	.4375	1 15/64	1.2343
1/16	.0625	10	.1935	29/64	.4531	1 1/4	1.2500
52	.0635	9	.1960	15/32	.4687	1 9/32	1.2812
51	.0670	8	.1990	31/64	.4844	1 5/16	1.3125
50	.0700	7	.2010	1/2	.5000	1 11/32	1.3437
49	.0730	13/64	.2031	33/64	.5156	1 3/8	1.3750
48	.0760	6	.2040	17/32	.5312	1 13/32	1.4062
5/64	.0781	5	.2055	35/64	.5468	1 7/16	1.4375
47	.0785	4	.2090	9/16	.5625	1 15/32	1.4687
46	.0810	3	.2130	37/64	.5781	1 1/2	1.5000
45	.0820	7/32	.2187	19/32	.5937	1 17/32	1.5312
44	.0860	2	.2210	39/64	.6093	1 9/16	1.5625
43	.0890	1	.2280	5/8	.6250	1 19/32	1.5937
42	.0935	A	.2340	41/64	.6406	1 5/8	1.6250
3/32	.0937	15/64	.2344	21/32	.6562	1 21/32	1.6562
41	.0960	B	.2380	43/64	.6718	1 11/16	1.6875
40	.0980	C	.2420	11/16	.6875	1 23/32	1.7187
39	.0995	D	.2460	45/64	.7031	1 3/4	1.7500
38	.1015	E-1/4	.2500	23/32	.7187		
37	.1040	F	.2570	47/64	.7343		
36	.1065	G	.2610	3/4	.7500		

DECIMAL EQUIVALENTS

OF PARTS OF AN INCH

1/64	.015625
1/32	.03125
3/64	.046875
1/16	.0625
5/64	.078125
3/32	.09375
7/64	.109375
1/8	.125
9/64	.140625
5/32	.15625
11/64	.171875
3/16	.1875
13/64	.203125
7/32	.21875
15/64	.234375
1/4	.25
17/64	.265625
9/32	.28125
19/64	.296875
5/16	.3125
21/64	.328125
11/32	.34375
23/64	.359375
3/8	.375
25/64	.390625
13/32	.40625
27/64	.421875
7/16	.4375
29/64	.453125
15/32	.46875
31/64	.484375
1/2	.5
33/64	.515625
17/32	.53125
35/64	.546875
9/16	.5625
37/64	.578125
19/32	.59375
39/64	.609375
5/8	.625
41/64	.640625
21/32	.65625
43/64	.671875
11/16	.6875
45/64	.703125
23/32	.71875
47/64	.734375
3/4	.75
49/64	.765625
25/32	.78125
51/64	.796875
13/16	.8125
53/64	.828125
27/32	.84375
55/64	.859375
7/8	.875
57/64	.890625
29/32	.90625
59/64	.921875
15/16	.9375
61/64	.953125
31/32	.96875
63/64	.984375
1	1.

TRIGONOMETRIC FUNCTIONS

0° READ DOWN

′	sin	tan	cot	cos	
0	.00000	.00000	∞	1.0000	60
1	029	029	3437.7	000	59
2	058	058	1718.9	000	58
3	087	087	1145.9	000	57
4	116	116	859.44	000	56
5	145	145	687.55	000	55
6	175	175	572.96	000	54
7	204	204	491.11	000	53
8	00233	.00233	429.72	000	52
9	262	262	381.97	000	51
10	291	291	343.77	1.0000	50
11	320	320	312.52	.99999	49
12	349	349	286.48	999	48
13	378	378	264.44	999	47
14	407	407	245.55	999	46
15	436	436	229.18	999	45
16	465	465	214.86	999	44
17	.00495	.00495	202.22	999	43
18	524	524	190.98	999	42
19	553	553	180.93	998	41
20	582	582	171.89	.99998	40
21	611	611	163.70	998	39
22	640	640	156.26	998	38
23	669	669	149.47	998	37
24	698	698	143.24	998	36
25	.00727	.00727	137.51	997	35
26	756	756	132.22	997	34
27	785	785	127.32	997	33
28	814	815	122.77	997	32
29	844	844	118.54	996	31
30	873	873	114.59	.99996	30
31	902	902	110.89	996	29
32	931	931	107.43	996	28
33	960	960	104.17	995	27
34	.00989	.00989	101.11	995	26
35	.01018	.01018	98.218	995	25
36	047	047	95.489	995	24
37	076	076	92.908	994	23
38	105	105	90.463	994	22
39	134	135	88.144	994	21
40	164	164	85.940	.99993	20
41	193	193	83.844	993	19
42	222	222	81.847	993	18
43	.01251	251	79.943	992	17
44	280	.01280	78.126	992	16
45	309	309	76.390	991	15
46	338	338	74.729	991	14
47	367	367	73.139	991	13
48	396	396	71.615	990	12
49	425	425	70.153	990	11
50	454	455	68.750	.99989	10
51	483	484	67.402	989	9
52	.01513	.01513	66.105	989	8
53	542	542	64.858	988	7
54	571	571	63.657	988	6
55	600	600	62.499	987	5
56	629	629	61.383	987	4
57	658	658	60.306	986	3
58	687	687	59.266	986	2
59	716	716	58.261	985	1
60	.01745	.01746	57.290	.99985	0
	cos	cot	tan	sin	′

89° READ UP

1° READ DOWN

′	sin	tan	cot	cos	
0	.01745	.01746	57.290	.99985	60
1	774	775	56.351	984	59
2	803	804	55.442	984	58
3	832	833	54.561	983	57
4	862	862	53.709	983	56
5	891	891	52.882	982	55
6	920	920	52.081	982	54
7	949	949	51.303	981	53
8	.01978	.01978	50.549	980	52
9	.02007	.02007	49.816	980	51
10	036	036	49.104	.99979	50
11	065	066	48.412	979	49
12	094	095	47.740	978	48
13	123	124	47.085	977	47
14	152	153	46.449	977	46
15	181	182	45.829	976	45
16	211	211	45.226	976	44
17	240	.02240	44.639	975	43
18	269	269	44.066	974	42
19	298	298	43.508	974	41
20	.02327	328	42.964	.99973	40
21	356	357	42.433	972	39
22	385	386	41.916	972	38
23	414	415	41.411	971	37
24	443	444	40.917	970	36
25	472	473	40.436	969	35
26	501	.02502	39.965	969	34
27	530	531	39.506	968	33
28	560	560	39.057	967	32
29	589	589	38.618	966	31
30	.02618	619	38.188	.99966	30
31	647	648	37.769	965	29
32	676	677	37.358	964	28
33	705	706	36.956	963	27
34	734	735	36.563	963	26
35	763	.02764	36.178	962	25
36	792	793	35.801	961	24
37	.02821	822	35.431	960	23
38	850	851	35.070	959	22
39	879	881	34.715	959	21
40	908	910	34.368	.99958	20
41	938	939	34.027	957	19
42	967	968	33.694	956	18
43	.02996	.02997	33.366	955	17
44	.03025	.03026	33.045	954	16
45	054	055	32.730	953	15
46	083	084	32.421	952	14
47	112	114	32.118	952	13
48	141	143	31.821	951	12
49	170	172	31.528	950	11
50	199	201	31.242	.99949	10
51	228	230	30.960	948	9
52	.03257	.03259	30.683	947	8
53	286	288	30.412	946	7
54	316	317	30.145	945	6
55	345	346	29.882	944	5
56	374	376	29.624	943	4
57	403	405	29.371	942	3
58	432	434	29.122	941	2
59	461	463	28.877	940	1
60	.03490	.03492	28.636	.99939	0
	cos	cot	tan	sin	′

88° READ UP

TRIGONOMETRIC FUNCTIONS

2° READ DOWN 3°

′	sin	tan	cot	cos	
0	.03490	.03492	28.636	.99939	60
1	519	521	.399	938	59
2	548	550	28.166	937	58
3	577	579	27.937	936	57
4	606	609	.712	935	56
5	635	638	.490	934	55
6	664	667	.271	933	54
7	693	696	27.057	932	53
8	723	.03725	26.845	931	52
9	.03752	754	.637	930	51
10	781	783	.432	.99929	50
11	810	812	.230	927	49
12	839	842	26.031	926	48
13	868	871	25.835	925	47
14	897	900	.642	924	46
15	926	929	.452	923	45
16	955	958	.264	922	44
17	.03984	.03987	25.080	921	43
18	.04013	.04016	24.898	919	42
19	042	046	.719	918	41
20	071	075	.542	.99917	40
21	100	104	.368	916	39
22	129	133	.196	915	38
23	159	162	24.026	913	37
24	188	191	23.859	912	36
25	217	220	.695	911	35
26	246	.04250	.532	910	34
27	.04275	279	.372	909	33
28	304	308	.214	907	32
29	333	337	23.058	906	31
30	362	366	22.904	.99905	30
31	391	395	.752	904	29
32	420	424	.602	902	28
33	449	454	.454	901	27
34	478	.04483	.308	900	26
35	.04507	512	.164	898	25
36	536	541	22.022	897	24
37	565	570	21.881	896	23
38	594	599	.743	894	22
39	623	628	.606	893	21
40	653	658	.470	.99892	20
41	682	687	.337	890	19
42	.04711	.04716	.205	889	18
43	740	745	21.075	888	17
44	769	774	20.946	886	16
45	798	803	.819	885	15
46	827	833	.693	883	14
47	856	862	.569	882	13
48	885	891	.446	881	12
49	914	920	.325	879	11
50	943	949	.206	.99878	10
51	.04972	.04978	20.087	876	9
52	.05001	.05007	19.970	875	8
53	030	037	.855	873	7
54	059	066	.740	872	6
55	088	095	.627	870	5
56	117	124	.516	869	4
57	146	153	.405	867	3
58	175	182	.296	866	2
59	205	212	.188	864	1
60	.05234	.05241	19.081	.99863	0
	cos	cot	tan	sin	′

′	sin	tan	cot	cos	
0	.05234	.05241	19.081	.99863	60
1	263	270	18.976	861	59
2	292	299	.871	860	58
3	321	328	.768	858	57
4	350	357	.666	857	56
5	379	387	.564	855	55
6	408	416	.464	854	54
7	437	445	.366	852	53
8	466	474	.268	851	52
9	.05495	.05503	.171	849	51
10	524	533	18.075	.99847	50
11	553	562	17.980	846	49
12	582	591	.886	844	48
13	611	620	.793	842	47
14	640	649	.702	841	46
15	669	678	.611	839	45
16	698	708	.521	838	44
17	.05727	737	.431	836	43
18	756	.05766	.343	834	42
19	785	795	.256	833	41
20	814	824	.169	.99831	40
21	844	854	17.084	829	39
22	873	883	16.999	827	38
23	902	912	.915	826	37
24	931	941	.832	824	36
25	960	970	.750	822	35
26	.05989	.05999	.668	821	34
27	.06018	.06029	.587	819	33
28	047	058	16.507	817	32
29	076	087	.428	815	31
30	105	116	.350	.99813	30
31	134	145	.272	812	29
32	163	175	.195	810	28
33	192	204	.119	808	27
34	221	233	16.043	806	26
35	.06250	262	15.969	804	25
36	279	.06291	.895	803	24
37	308	321	.821	801	23
38	337	350	.748	799	22
39	366	379	.676	797	21
40	395	408	.605	.99795	20
41	424	438	.534	793	19
42	453	467	15.464	792	18
43	.06482	496	.394	790	17
44	511	.06525	.325	788	16
45	540	554	.257	786	15
46	569	584	.189	784	14
47	598	613	.122	782	13
48	627	642	15.056	780	12
49	656	671	14.990	778	11
50	685	700	.924	.99776	10
51	.06714	730	.860	774	9
52	743	.06759	.795	772	8
53	773	788	.732	770	7
54	802	817	.669	768	6
55	831	847	.606	766	5
56	860	876	.544	764	4
57	889	905	.482	762	3
58	918	934	.421	760	2
59	947	963	.361	758	1
60	.06976	.06993	14.301	.99756	0
	cos	cot	tan	sin	′

87° READ UP 86°

TRIGONOMETRIC FUNCTIONS

READ DOWN 5°

′	sin	tan	cot	cos	
0	.06976	.06993	14.301	.99756	60
1	.07005	.07022	.241	754	59
2	034	051	.182	752	58
3	063	080	.124	750	57
4	092	110	.065	748	56
5	121	139	14.008	746	55
6	150	168	13.951	744	54
7	179	197	.894	742	53
8	208	227	.838	740	52
9	237	.07256	.782	738	51
10	.07266	285	.727	.99736	50
11	295	314	.672	734	49
12	324	344	.617	731	48
13	353	373	.563	729	47
14	382	402	13.510	727	46
15	411	431	.457	725	45
16	440	461	.404	723	44
17	469	490	.352	721	43
18	.07498	.07519	.300	719	42
19	527	548	.248	716	41
20	556	578	.197	.99714	40
21	585	607	.146	712	39
22	614	636	.096	710	38
23	643	665	13.046	708	37
24	672	695	12.996	705	36
25	701	724	.947	703	35
26	.07730	.07753	.898	701	34
27	759	782	.850	699	33
28	788	812	.801	696	32
29	817	841	.754	694	31
30	846	870	.706	.99692	30
31	875	899	.659	689	29
32	904	929	12.612	687	28
33	933	958	.566	685	27
34	962	.07987	.520	683	26
35	.07991	.08017	.474	680	25
36	.08020	046	.429	678	24
37	049	075	.384	676	23
38	078	104	12.339	673	22
39	107	134	.295	671	21
40	136	163	.251	.99668	20
41	165	192	.207	666	19
42	194	221	.163	664	18
43	223	.08251	.120	661	17
44	.08252	280	.077	659	16
45	281	309	12.035	657	15
46	310	339	11.992	654	14
47	339	368	.950	652	13
48	368	397	.909	649	12
49	397	427	.867	647	11
50	426	456	.826	.99644	10
51	455	485	.785	642	9
52	.08484	.08514	.745	639	8
53	513	544	.705	637	7
54	542	573	11.664	635	6
55	571	602	.625	632	5
56	600	632	.585	630	4
57	629	661	.546	627	3
58	658	690	.507	625	2
59	687	720	.468	622	1
60	.08716	.08749	11.430	.99619	0
	cos	cot	tan	sin	′

′	sin	tan	cot	cos	
0	.08716	.08749	11.430	.99619	60
1	745	778	.392	617	59
2	774	807	.354	614	58
3	803	837	.316	612	57
4	831	866	.279	609	56
5	860	895	.242	607	55
6	889	925	.205	604	54
7	918	954	.168	602	53
8	947	.08983	.132	599	52
9	.08976	.09013	.095	596	51
10	.09005	042	.059	.99594	50
11	034	071	11.024	591	49
12	063	101	10.988	588	48
13	092	130	.953	586	47
14	121	159	.918	583	46
15	150	189	.883	580	45
16	179	218	.848	578	44
17	208	.09247	.814	575	43
18	.09237	277	.780	572	42
19	266	306	.746	570	41
20	295	335	.712	.99567	40
21	324	365	.678	564	39
22	353	394	10.645	562	38
23	382	423	.612	559	37
24	411	453	.579	556	36
25	440	.09482	.546	553	35
26	.09469	511	.514	551	34
27	498	541	.481	548	33
28	527	570	.449	545	32
29	556	600	.417	542	31
30	585	629	.385	.99540	30
31	614	658	.354	537	29
32	642	688	10.322	534	28
33	671	.09717	.291	531	27
34	700	746	.260	528	26
35	.09729	776	.229	526	25
36	758	805	.199	523	24
37	787	834	.168	520	23
38	816	864	.138	517	22
39	845	893	.108	514	21
40	874	923	.078	.99511	20
41	903	952	.048	508	19
42	932	.09981	10.019	506	18
43	961	.10011	9.9893	503	17
44	.09990	040	.9601	500	16
45	.10019	069	.9310	497	15
46	048	099	.9021	494	14
47	077	128	.8734	491	13
48	106	158	.8448	488	12
49	135	187	.8164	485	11
50	164	216	.7882	.99482	10
51	192	.10246	.7601	479	9
52	221	275	9.7322	476	8
53	.10250	305	.7044	473	7
54	279	334	.6768	470	6
55	308	363	.6493	467	5
56	337	393	.6220	464	4
57	366	422	.5949	461	3
58	395	452	.5679	458	2
59	424	481	.5411	455	1
60	.10453	.10510	9.5144	.99452	0
	cos	cot	tan	sin	′

85° READ UP 84°

TRIGONOMETRIC FUNCTIONS

6° READ DOWN

′	sin	tan	cot	cos	
0	.10453	.10510	9.5144	.99452	60
1	482	540	.4878	449	59
2	511	569	.4614	446	58
3	540	599	.4352	443	57
4	569	628	.4090	440	56
5	597	657	.3831	437	55
6	626	687	.3572	434	54
7	655	716	.3315	431	53
8	684	.10746	.3060	428	52
9	.10713	775	.2806	424	51
10	742	805	9.2553	.99421	50
11	771	834	.2302	418	49
12	800	863	.2052	415	48
13	829	893	.1803	412	47
14	858	922	.1555	409	46
15	887	952	.1309	406	45
16	916	.10981	.1065	402	44
17	945	.11011	.0821	399	43
18	.10973	040	.0579	396	42
19	.11002	070	.0338	393	41
20	031	099	9.0098	.99390	40
21	060	128	8.9860	386	39
22	089	158	.9623	383	38
23	118	187	.9387	380	37
24	147	217	.9152	377	36
25	176	.11246	.8919	374	35
26	205	276	.8686	370	34
27	234	305	.8455	367	33
28	.11263	335	.8225	364	32
29	291	364	.7996	360	31
30	320	394	.7769	.99357	30
31	349	423	8.7542	354	29
32	378	452	.7317	351	28
33	407	.11482	.7093	347	27
34	436	511	.6870	344	26
35	465	541	.6648	341	25
36	494	570	.6427	337	24
37	.11523	600	.6208	334	23
38	552	629	.5989	331	22
39	580	659	.5772	327	21
40	609	688	.5555	.99324	20
41	638	.11718	8.5340	320	19
42	667	747	.5126	317	18
43	696	777	.4913	314	17
44	725	806	.4701	310	16
45	.11754	836	.4490	307	15
46	783	865	.4280	303	14
47	812	895	.4071	300	13
48	840	924	.3863	297	12
49	869	954	.3656	293	11
50	898	.11983	.3450	.99290	10
51	927	.12013	8.3245	286	9
52	956	042	.3041	283	8
53	.11985	072	.2838	279	7
54	.12014	101	.2636	276	6
55	043	131	.2434	272	5
56	071	160	.2234	269	4
57	100	190	.2035	265	3
58	129	219	.1837	262	2
59	158	249	.1640	258	1
60	.12187	.12278	8.1443	.99255	0
	cos	cot	tan	sin	′

83° READ UP

7°

′	sin	tan	cot	cos	
0	.12187	.12278	8.1443	.99255	60
1	216	308	.1248	251	59
2	245	338	.1054	248	58
3	274	367	.0860	244	57
4	302	397	.0667	240	56
5	331	426	.0476	237	55
6	360	456	.0285	233	54
7	389	485	8.0095	230	53
8	418	.12515	7.9906	226	52
9	.12447	544	.9718	222	51
10	476	574	.9530	.99219	50
11	504	603	.9344	215	49
12	533	633	.9158	211	48
13	562	662	.8973	208	47
14	591	692	.8789	204	46
15	620	722	.8606	200	45
16	649	.12751	7.8424	197	44
17	678	781	.8243	193	43
18	.12706	810	.8062	189	42
19	735	840	.7882	186	41
20	764	869	.7704	.99182	40
21	793	899	.7525	178	39
22	822	929	.7348	175	38
23	851	958	.7171	171	37
24	880	.12988	.6996	167	36
25	908	.13017	7.6821	163	35
26	937	047	.6647	160	34
27	966	076	.6473	156	33
28	.12995	106	.6301	152	32
29	.13024	136	.6129	148	31
30	053	165	.5958	.99144	30
31	081	195	.5787	141	29
32	110	224	.5618	137	28
33	139	.13254	.5449	133	27
34	168	284	7.5281	129	26
35	197	313	.5113	125	25
36	.13226	343	.4947	122	24
37	254	372	.4781	118	23
38	283	402	.4615	114	22
39	312	432	.4451	110	21
40	341	461	.4287	.99106	20
41	370	.13491	.4124	102	19
42	399	521	.3962	098	18
43	427	550	7.3800	094	17
44	.13456	580	.3639	091	16
45	485	609	.3479	087	15
46	514	639	.3319	083	14
47	543	669	.3160	079	13
48	572	698	.3002	075	12
49	600	.13728	.2844	071	11
50	629	758	.2687	.99067	10
51	658	787	7.2531	063	9
52	.13687	817	.2375	059	8
53	716	846	.2220	055	7
54	744	876	.2066	051	6
55	773	906	.1912	047	5
56	802	935	.1759	043	4
57	831	965	.1607	039	3
58	860	.13995	.1455	035	2
59	889	.14024	.1304	031	1
60	.13917	.14054	7.1154	.99027	0
	cos	cot	tan	sin	′

82°

TRIGONOMETRIC FUNCTIONS

8° READ DOWN 9°

'	sin	tan	cot	cos	
0	.13917	.14054	7.1154	.99027	60
1	946	084	.1004	023	59
2	.13975	113	.0855	019	58
3	.14004	143	.0706	015	57
4	033	173	.0558	011	56
5	061	202	.0410	006	55
6	090	232	.0264	.99002	54
7	119	262	7.0117	.98998	53
8	148	.14291	6.9972	994	52
9	177	321	.9827	990	51
10	205	351	.9682	986	50
11	.14234	381	.9538	982	49
12	263	410	.9395	978	48
13	292	440	.9252	973	47
14	320	470	.9110	969	46
15	349	499	.8969	965	45
16	378	.14529	.8828	961	44
17	407	559	6.8687	.98957	43
18	436	588	.8548	953	42
19	464	618	.8408	948	41
20	.14493	648	.8269	944	40
21	522	678	.8131	940	39
22	551	707	.7994	936	38
23	580	737	.7856	931	37
24	608	.14767	.7720	927	36
25	637	796	6.7584	.98923	35
26	666	826	.7448	919	34
27	695	856	.7313	914	33
28	.14723	886	.7179	910	32
29	752	915	.7045	906	31
30	781	945	.6912	902	30
31	810	.14975	.6779	897	29
32	838	.15005	.6646	893	28
33	867	034	.6514	889	27
34	896	064	6.6383	.98884	26
35	925	094	.6252	880	25
36	954	124	.6122	876	24
37	.14982	153	.5992	871	23
38	.15011	183	.5863	867	22
39	040	213	.5734	863	21
40	069	243	.5606	858	20
41	097	.15272	.5478	854	19
42	126	302	.5350	849	18
43	155	332	6.5223	.98845	17
44	184	362	.5097	841	16
45	.15212	391	.4971	836	15
46	241	421	.4846	832	14
47	270	451	.4721	827	13
48	299	481	.4596	823	12
49	327	511	.4472	818	11
50	356	.15540	.4348	814	10
51	385	570	.4225	809	9
52	.15414	600	6.4103	.98805	8
53	442	630	.3980	800	7
54	471	660	.3859	796	6
55	500	689	.3737	791	5
56	529	719	.3617	787	4
57	557	749	.3496	782	3
58	586	779	.3376	778	2
59	615	809	.3257	773	1
60	.15643	.15838	6.3138	.98769	0
	cos	cot	tan	sin	'

'	sin	tan	cot	cos	
0	.15643	.15838	6.3138	.98769	60
1	672	868	.3019	764	59
2	701	898	.2901	760	58
3	730	928	.2783	755	57
4	758	958	.2666	751	56
5	787	.15988	.2549	746	55
6	.15816	.16017	.2432	741	54
7	845	047	.2316	737	53
8	873	077	.2200	732	52
9	902	107	6.2085	728	51
10	931	137	.1970	.98723	50
11	959	167	.1856	718	49
12	.15988	196	.1742	714	48
13	.16017	226	.1628	709	47
14	046	.16256	.1515	704	46
15	074	286	.1402	700	45
16	103	316	.1290	695	44
17	132	346	.1178	690	43
18	160	376	6.1066	686	42
19	189	405	.0955	681	41
20	218	435	.0844	.98676	40
21	246	465	.0734	671	39
22	.16275	.16495	.0624	667	38
23	304	525	.0514	662	37
24	333	555	.0405	657	36
25	361	585	.0296	652	35
26	390	615	.0188	648	34
27	419	645	6.0080	643	33
28	447	674	5.9972	638	32
29	476	704	.9865	633	31
30	505	.16734	.9758	.98629	30
31	.16533	764	.9651	624	29
32	562	794	.9545	619	28
33	591	824	.9439	614	27
34	620	854	.9333	609	26
35	648	884	.9228	604	25
36	677	914	5.9124	600	24
37	706	944	.9019	595	23
38	734	.16974	.8915	590	22
39	.16763	.17004	.8811	585	21
40	792	033	.8708	.98580	20
41	820	063	.8605	575	19
42	849	093	.8502	570	18
43	878	123	.8400	565	17
44	906	153	5.8298	561	16
45	935	183	.8197	556	15
46	964	.17213	.8095	551	14
47	.16992	243	.7994	546	13
48	.17021	273	.7894	541	12
49	050	303	.7794	536	11
50	078	333	.7694	.98531	10
51	107	363	.7594	526	9
52	136	393	5.7495	521	8
53	164	.17423	.7396	516	7
54	.17193	453	.7297	511	6
55	222	483	.7199	506	5
56	250	513	.7101	501	4
57	279	543	.7004	496	3
58	308	573	.6906	491	2
59	336	603	.6809	486	1
60	.17365	.17633	5.6713	.98481	0
	cos	cot	tan	sin	'

81° READ UP 80°

TRIGONOMETRIC FUNCTIONS

10° READ DOWN 11°

′	sin	tan	cot	cos	
0	.17365	.17633	5.6713	.98481	60
1	393	663	.6617	476	59
2	422	693	.6521	471	58
3	451	723	.6425	466	57
4	479	753	.6329	461	56
5	508	783	.6234	455	55
6	537	.17813	.6140	450	54
7	.17565	843	.6045	445	53
8	594	873	.5951	440	52
9	623	903	.5857	435	51
10	651	933	5.5764	.98430	50
11	680	963	.5671	425	49
12	708	.17993	.5578	420	48
13	737	.18023	.5485	414	47
14	766	053	.5393	409	46
15	.17794	083	.5301	404	45
16	823	113	5209	399	44
17	852	143	5118	394	43
18	880	173	.5026	389	42
19	909	203	.4936	383	41
20	937	233	5.4845	.98378	40
21	966	.18263	.4755	373	39
22	.17995	293	.4665	368	38
23	.18023	323	.4575	362	37
24	052	353	.4486	357	36
25	081	384	.4397	352	35
26	109	414	.4308	347	34
27	138	444	.4219	341	33
28	166	474	.4131	336	32
29	195	.18504	.4043	331	31
30	224	534	5.3955	.98325	30
31	252	564	.3868	320	29
32	.18281	594	.3781	315	28
33	309	624	.3694	310	27
34	338	654	.3607	304	26
35	367	684	.3521	299	25
36	395	714	.3435	294	24
37	424	.18745	.3349	288	23
38	452	775	.3263	283	22
39	481	805	.3178	277	21
40	.18509	835	5.3093	.98272	20
41	538	865	.3008	267	19
42	567	895	.2924	261	18
43	595	925	.2839	256	17
44	624	955	.2755	250	16
45	652	.18986	.2672	245	15
46	681	.19016	.2588	240	14
47	710	046	.2505	234	13
48	738	076	.2422	229	12
49	.18767	106	.2339	223	11
50	795	136	5.2257	.98218	10
51	824	166	.2174	212	9
52	852	197	.2092	207	8
53	881	.19227	.2011	201	7
54	910	257	.1929	196	6
55	938	287	.1848	190	5
56	967	317	.1767	185	4
57	.18995	347	.1686	179	3
58	.19024	378	.1606	174	2
59	052	408	.1526	168	1
60	.19081	.19438	5.1446	.98163	0
	cos	cot	tan	sin	′

′	sin	tan	cot	cos	
0	.19081	.19438	5.1446	.98163	60
1	109	468	.1366	157	59
2	138	498	.1286	152	58
3	167	529	.1207	146	57
4	195	559	.1128	140	56
5	224	589	.1049	135	55
6	252	619	.0970	129	54
7	281	649	.0892	124	53
8	.19309	680	.0814	118	52
9	338	.19710	5.0736	.98112	51
10	366	740	.0658	107	50
11	395	770	.0581	101	49
12	423	801	.0504	096	48
13	452	831	.0427	090	47
14	481	861	.0350	084	46
15	509	891	.0273	079	45
16	.19538	921	.0197	073	44
17	566	952	.0121	067	43
18	595	.19982	5.0045	061	42
19	623	.20012	4.9969	.98056	41
20	652	042	.9894	050	40
21	680	073	.9819	044	39
22	709	103	.9744	039	38
23	737	133	.9669	033	37
24	.19766	164	.9594	027	36
25	794	194	.9520	021	35
26	823	.20224	.9446	016	34
27	851	254	4.9372	010	33
28	880	285	.9298	.98004	32
29	908	315	.9225	.97998	31
30	937	345	.9152	992	30
31	965	376	.9078	987	29
32	.19994	406	.9006	981	28
33	.20022	436	.8933	975	27
34	051	.20466	.8860	969	26
35	079	497	4.8788	963	25
36	108	527	.8716	958	24
37	136	557	.8644	.97952	23
38	165	588	.8573	946	22
39	193	618	.8501	940	21
40	222	648	.8430	934	20
41	250	679	.8359	928	19
42	.20279	709	.8288	922	18
43	307	.20739	.8218	916	17
44	336	770	4.8147	.97910	16
45	364	800	.8077	905	15
46	393	830	.8007	899	14
47	421	861	.7937	893	13
48	450	891	.7867	887	12
49	478	921	.7798	881	11
50	507	952	.7729	875	10
51	.20535	.20982	.7659	869	9
52	563	.21013	4.7591	.97863	8
53	592	043	.7522	857	7
54	620	073	.7453	851	6
55	649	104	.7385	845	5
56	677	134	.7317	839	4
57	706	164	.7249	833	3
58	734	195	.7181	827	2
59	763	225	.7114	821	1
60	.20791	.21256	4.7046	.97815	0
	cos	cot	tan	sin	′

79° READ UP 78°

TRIGONOMETRIC FUNCTIONS

12° READ DOWN 13°

′	sin	tan	cot	cos	
0	.20791	.21256	4.7046	.97815	60
1	820	286	4.6979	809	59
2	848	316	912	803	58
3	877	347	845	797	57
4	905	377	779	791	56
5	933	408	712	784	55
6	962	438	646	778	54
7	.20990	469	580	772	53
8	.21019	.21499	4.6514	766	52
9	047	529	448	760	51
10	076	560	382	.97754	50
11	104	590	317	748	49
12	132	621	252	742	48
13	161	651	187	735	47
14	189	682	122	729	46
15	218	712	4.6057	723	45
16	.21246	.21743	4.5993	717	44
17	275	773	928	711	43
18	303	804	864	705	42
19	331	834	800	698	41
20	360	864	736	.97692	40
21	388	895	673	686	39
22	417	925	609	680	38
23	445	956	4.5546	673	37
24	474	.21986	483	667	36
25	.21502	.22017	420	661	35
26	530	047	357	655	34
27	559	078	294	648	33
28	587	108	232	642	32
29	616	139	169	636	31
30	644	169	107	.97630	30
31	672	200	4.5045	623	29
32	701	231	4.4983	617	28
33	729	.22261	922	611	27
34	.21758	292	860	604	26
35	786	322	799	598	25
36	814	353	737	592	24
37	843	383	676	585	23
38	871	414	615	579	22
39	899	444	555	573	21
40	928	475	4.4494	.97566	20
41	956	.22505	434	560	19
42	.21985	536	373	553	18
43	.22013	567	313	547	17
44	041	597	253	541	16
45	070	628	194	534	15
46	098	658	134	528	14
47	126	689	075	521	13
48	155	719	4.4015	515	12
49	183	.22750	4.3956	508	11
50	212	781	897	.97502	10
51	240	811	838	496	9
52	.22268	842	779	489	8
53	297	872	721	483	7
54	325	903	662	476	6
55	353	934	604	470	5
56	382	964	546	463	4
57	410	.22995	488	457	3
58	438	.23026	430	450	2
59	467	056	372	444	1
60	.22495	.23087	4.3315	.97437	0
	cos	cot	tan	sin	′

′	sin	tan	cot	cos	
0	.22495	.23087	4.3315	.97437	60
1	523	117	257	430	59
2	552	148	200	424	58
3	580	179	143	417	57
4	608	209	086	411	56
5	637	240	4.3029	404	55
6	665	271	4.2972	398	54
7	693	23301	916	391	53
8	.22722	332	859	384	52
9	750	363	803	378	51
10	778	393	747	.97371	50
11	807	424	691	365	49
12	835	455	635	358	48
13	863	485	580	351	47
14	892	516	4.2524	345	46
15	920	.23547	468	338	45
16	948	578	413	331	44
17	.22977	608	358	325	43
18	.23005	639	303	318	42
19	033	670	248	311	41
20	062	700	193	.97304	40
21	090	731	139	298	39
22	118	.23762	084	291	38
23	146	793	4.2030	284	37
24	175	823	4.1976	278	36
25	203	854	922	271	35
26	231	885	868	264	34
27	.23260	916	814	257	33
28	288	946	760	251	32
29	316	.23977	706	244	31
30	345	.24008	653	.97237	30
31	373	039	600	230	29
32	401	069	547	223	28
33	429	100	4.1493	217	27
34	458	131	441	210	26
35	.23486	162	388	203	25
36	514	193	335	196	24
37	542	223	282	189	23
38	571	.24254	230	182	22
39	599	285	178	176	21
40	627	316	126	.97169	20
41	656	347	074	162	19
42	684	377	4.1022	155	18
43	712	408	4.0970	148	17
44	.23740	439	918	141	16
45	769	.24470	867	134	15
46	797	501	815	127	14
47	825	532	764	120	13
48	853	562	713	113	12
49	882	593	662	106	11
50	910	624	611	.97100	10
51	938	655	560	093	9
52	966	.24686	4.0509	086	8
53	.23995	717	459	079	7
54	.24023	747	408	072	6
55	051	778	358	065	5
56	079	809	308	058	4
57	108	840	257	051	3
58	136	871	207	044	2
59	164	902	158	037	1
60	.24192	.24933	4.0108	.97030	0
	cos	cot	tan	sin	′

77° READ UP 76°

TRIGONOMETRIC FUNCTIONS

14° READ DOWN

′	sin	tan	cot	cos	
0	.24192	.24933	4.0108	.97030	60
1	220	964	058	023	59
2	249	.24995	4.0009	015	58
3	277	.25026	3.9959	008	57
4	305	056	910	.97001	56
5	333	087	861	.96994	55
6	362	118	812	987	54
7	390	149	763	980	53
8	418	180	714	973	52
9	.24446	211	665	966	51
10	474	242	617	959	50
11	503	.25273	568	952	49
12	531	304	3.9520	945	48
13	559	335	471	.96937	47
14	587	366	423	930	46
15	615	397	375	923	45
16	644	428	327	916	44
17	672	459	279	909	43
18	700	.25490	232	902	42
19	.24728	521	184	894	41
20	756	552	136	887	40
21	784	583	089	.96880	39
22	813	614	3.9042	873	38
23	841	645	3.8995	866	37
24	869	676	947	858	36
25	897	707	900	851	35
26	925	.25738	854	844	34
27	954	769	807	837	33
28	.24982	800	760	829	32
29	.25010	831	714	.96822	31
30	038	862	3.8667	815	30
31	066	893	621	807	29
32	094	924	575	800	28
33	122	955	528	793	27
34	151	.25986	482	786	26
35	179	.26017	436	778	25
36	207	048	391	771	24
37	.25235	079	3.8345	.96764	23
38	263	110	299	756	22
39	291	141	254	749	21
40	320	172	208	742	20
41	348	203	163	734	19
42	376	235	118	727	18
43	404	.26266	073	719	17
44	.25432	297	3.8028	712	16
45	460	328	3.7983	.96705	15
46	488	359	938	697	14
47	516	390	893	690	13
48	545	421	848	682	12
49	573	452	804	675	11
50	601	483	760	667	10
51	629	515	715	660	9
52	.25657	.26546	3.7671	653	8
53	685	577	627	.96645	7
54	713	608	583	638	6
55	741	639	539	630	5
56	769	670	495	623	4
57	798	701	451	615	3
58	826	733	408	608	2
59	854	764	364	600	1
60	.25882	.26795	3.7321	.96593	0
	cos	cot	tan	sin	′

75° READ UP

15° READ DOWN

′	sin	tan	cot	cos	
0	.25882	.26795	3.7321	.96593	60
1	910	826	277	585	59
2	938	857	234	578	58
3	966	888	191	570	57
4	.25994	920	148	562	56
5	.26022	951	105	555	55
6	050	.26982	062	547	54
7	079	.27013	3.7019	540	53
8	107	044	3.6976	532	52
9	135	076	933	524	51
10	163	107	891	.96517	50
11	191	138	848	509	49
12	219	169	806	502	48
13	.26247	201	764	494	47
14	275	232	722	486	46
15	303	.27263	680	479	45
16	331	294	3.6638	471	44
17	359	326	596	463	43
18	387	357	554	456	42
19	415	388	512	448	41
20	443	419	470	.96440	40
21	.26471	451	429	433	39
22	500	.27482	387	425	38
23	528	513	346	417	37
24	556	545	3.6305	410	36
25	584	576	264	402	35
26	612	607	222	394	34
27	640	638	181	386	33
28	668	670	140	379	32
29	696	701	100	371	31
30	.26724	.27732	059	.96363	30
31	752	764	3.6018	355	29
32	780	795	3.5978	347	28
33	808	826	937	340	27
34	836	858	897	332	26
35	864	889	856	324	25
36	892	921	816	316	24
37	920	952	776	308	23
38	948	.27983	736	301	22
39	.26976	.28015	696	293	21
40	.27004	046	3.5656	.96285	20
41	032	077	616	277	19
42	060	109	576	269	18
43	088	140	536	261	17
44	116	172	497	253	16
45	144	203	457	246	15
46	172	.28234	418	238	14
47	200	266	379	230	13
48	228	297	3.5339	222	12
49	256	329	300	214	11
50	.27284	360	261	.96206	10
51	312	391	222	198	9
52	340	423	183	190	8
53	368	.28454	144	182	7
54	396	486	105	174	6
55	424	517	067	166	5
56	452	549	3.5028	158	4
57	480	580	3.4989	150	3
58	508	612	951	142	2
59	536	643	912	134	1
60	.27564	.28675	3.4874	.96126	0
	cos	cot	tan	sin	′

74° READ UP

TRIGONOMETRIC FUNCTIONS

16° READ DOWN 17°

′	sin	tan	cot	cos	
0	.27564	.28675	3.4874	.96126	60
1	592	706	836	118	59
2	620	738	798	110	58
3	648	769	760	102	57
4	676	801	722	094	56
5	704	832	684	086	55
6	731	864	646	078	54
7	.27759	895	608	.96070	53
8	787	927	3.4570	062	52
9	815	958	533	054	51
10	843	.28990	495	046	50
11	871	.29021	458	037	49
12	899	053	420	029	48
13	927	084	383	021	47
14	955	116	346	013	46
15	.27983	147	3.4308	.96005	45
16	.28011	179	271	.95997	44
17	039	210	234	989	43
18	067	.29242	197	981	42
19	095	274	160	972	41
20	123	305	124	964	40
21	150	337	087	956	39
22	178	368	050	948	38
23	206	400	3.4014	940	37
24	.28234	432	3.3977	931	36
25	262	.29463	941	.95923	35
26	290	495	904	915	34
27	318	526	868	907	33
28	346	558	832	898	32
29	374	590	796	890	31
30	402	621	759	882	30
31	429	653	723	874	29
32	457	685	687	865	28
33	.28485	.29716	3.3652	.95857	27
34	513	748	616	849	26
35	541	780	580	841	25
36	569	811	544	832	24
37	597	843	509	824	23
38	625	875	473	816	22
39	652	906	438	807	21
40	680	938	402	799	20
41	708	.29970	367	791	19
42	.28736	.30001	3.3332	.95782	18
43	764	033	297	774	17
44	792	065	261	766	16
45	820	097	226	757	15
46	847	128	191	749	14
47	875	160	156	740	13
48	903	192	122	732	12
49	931	224	087	724	11
50	959	255	052	715	10
51	.28987	.30287	3.3017	.95707	9
52	.29015	319	3.2983	698	8
53	042	351	948	690	7
54	070	382	914	681	6
55	098	414	879	673	5
56	126	446	845	664	4
57	154	478	811	656	3
58	182	509	777	647	2
59	209	541	743	639	1
60	.29237	.30573	3.2709	.95630	0
	cos	cot	tan	sin	′

′	sin	tan	cot	cos	
0	.29237	.30573	3.2709	.95630	60
1	265	605	675	622	59
2	293	637	641	613	58
3	321	669	607	605	57
4	348	700	573	596	56
5	376	732	539	588	55
6	404	764	506	579	54
7	432	.30796	3.2472	571	53
8	460	828	438	562	52
9	.29487	860	405	554	51
10	515	891	371	.95545	50
11	543	923	338	536	49
12	571	955	305	528	48
13	599	.30987	272	519	47
14	626	.31019	3.2238	511	46
15	654	051	205	502	45
16	682	083	172	493	44
17	710	115	139	485	43
18	.29737	147	106	476	42
19	765	178	073	467	41
20	793	210	041	.95459	40
21	821	242	3.2008	450	39
22	849	.31274	3.1975	441	38
23	876	306	943	433	37
24	904	338	910	424	36
25	932	370	878	415	35
26	960	402	845	407	34
27	.29987	434	813	398	33
28	.30015	466	780	389	32
29	043	.31498	3.1748	380	31
30	071	530	716	.95372	30
31	098	562	684	363	29
32	126	594	652	354	28
33	154	626	620	345	27
34	182	658	588	337	26
35	209	690	556	328	25
36	237	722	524	319	24
37	.30265	.31754	3.1492	310	23
38	292	786	460	301	22
39	320	818	429	293	21
40	348	850	397	.95284	20
41	376	882	366	275	19
42	403	914	334	260	18
43	431	946	303	257	17
44	459	.31978	3.1271	248	16
45	.30486	.32010	240	240	15
46	514	042	209	231	14
47	542	074	178	222	13
48	570	106	146	213	12
49	597	139	115	204	11
50	625	171	084	.95195	10
51	653	203	053	186	9
52	680	235	3.1022	177	8
53	.30708	.32267	3.0991	168	7
54	736	299	961	159	6
55	763	331	930	150	5
56	791	363	899	142	4
57	819	396	868	133	3
58	846	428	838	124	2
59	874	460	807	115	1
60	.30902	.32492	3.0777	.95106	0
	cos	cot	tan	sin	′

73° READ UP 72°

TRIGONOMETRIC FUNCTIONS

18° READ DOWN

′	sin	tan	cot	cos	
0	.30902	.32492	3.0777	.95106	60
1	929	524	746	097	59
2	957	556	716	088	58
3	.30985	588	686	079	57
4	.31012	621	655	070	56
5	040	653	625	061	55
6	068	685	595	.95052	54
7	095	717	565	043	53
8	123	.32749	535	033	52
9	151	782	3.0505	024	51
10	178	814	475	015	50
11	206	846	445	.95006	49
12	233	878	415	.94997	48
13	261	911	385	988	47
14	.31289	943	356	979	46
15	316	.32975	326	970	45
16	344	.33007	296	961	44
17	372	040	3.0267	952	43
18	399	072	237	943	42
19	427	104	208	933	41
20	454	136	178	.94924	40
21	482	169	149	915	39
22	.31510	201	120	906	38
23	537	233	090	897	37
24	565	.33266	061	888	36
25	593	298	032	878	35
26	620	330	3.0003	869	34
27	648	363	2.9974	860	33
28	675	395	945	.94851	32
29	703	427	916	842	31
30	730	460	887	832	30
31	.31758	.33492	858	823	29
32	786	524	829	814	28
33	813	557	800	805	27
34	841	589	772	795	26
35	868	621	2.9743	786	25
36	896	654	714	.94777	24
37	923	686	686	768	23
38	951	.33718	657	758	22
39	.31979	751	629	749	21
40	.32006	783	600	740	20
41	034	816	572	730	19
42	061	848	544	721	18
43	089	881	515	712	17
44	116	913	2.9487	.94702	16
45	144	945	459	693	15
46	171	.33978	431	684	14
47	199	.34010	403	674	13
48	227	043	375	665	12
49	254	075	347	656	11
50	.32282	108	319	646	10
51	309	140	2.9291	637	9
52	337	173	263	.94627	8
53	364	205	235	618	7
54	392	.34238	208	609	6
55	419	270	180	599	5
56	447	303	152	590	4
57	474	335	125	580	3
58	502	368	097	571	2
59	529	400	070	561	1
60	.32557	.34433	2.9042	.94552	0
	cos	cot	tan	sin	′

71° READ UP

19° READ DOWN

′	sin	tan	cot	cos	
0	.32557	.34433	2.9042	.94552	60
1	584	465	2.9015	542	59
2	612	498	2.8987	533	58
3	639	530	960	523	57
4	667	563	933	514	56
5	694	596	905	504	55
6	722	628	878	495	54
7	749	661	851	485	53
8	.32777	693	824	476	52
9	804	.34726	797	466	51
10	832	758	770	.94457	50
11	859	791	2.8743	447	49
12	887	824	716	438	48
13	914	856	689	428	47
14	942	889	662	418	46
15	969	922	636	409	45
16	.32997	954	609	399	44
17	.33024	.34987	582	390	43
18	051	.35020	556	380	42
19	079	052	529	370	41
20	106	085	2.8502	.94361	40
21	134	118	476	351	39
22	161	150	449	342	38
23	189	183	423	332	37
24	.33216	216	397	322	36
25	244	.35248	370	313	35
26	271	281	344	303	34
27	298	314	318	293	33
28	326	346	291	284	32
29	353	379	2.8265	274	31
30	381	412	239	.94264	30
31	.33408	.35445	213	254	29
32	436	477	187	245	28
33	463	510	161	235	27
34	490	543	135	225	26
35	518	576	109	215	25
36	545	608	083	206	24
37	573	641	057	196	23
38	.33600	674	032	186	22
39	627	.35707	2.8006	176	21
40	655	740	2.7980	.94167	20
41	682	772	955	157	19
42	710	805	929	147	18
43	737	838	903	137	17
44	764	871	878	127	16
45	.33792	904	852	118	15
46	819	937	2.7827	108	14
47	846	.35969	801	098	13
48	874	.36002	776	.94088	12
49	901	035	751	078	11
50	929	068	725	068	10
51	956	101	700	058	9
52	.33983	134	675	049	8
53	.34011	167	2.7650	039	7
54	038	.36199	625	029	6
55	065	232	600	019	5
56	093	265	575	.94009	4
57	120	298	550	.93999	3
58	147	331	525	989	2
59	175	364	500	979	1
60	.34202	.36397	2.7475	.93969	0
	cos	cot	tan	sin	′

70° READ UP

TRIGONOMETRIC FUNCTIONS

20° READ DOWN 21°

′	sin	tan	cot	cos	
0	.34202	.36397	2.7475	.93969	60
1	229	430	450	959	59
2	257	463	425	949	58
3	284	496	400	939	57
4	311	529	376	929	56
5	339	562	351	919	55
6	366	595	326	909	54
7	.34393	628	302	899	53
8	421	661	277	889	52
9	448	.36694	2.7253	879	51
10	475	727	228	.93869	50
11	503	760	204	859	49
12	530	793	179	849	48
13	557	826	155	839	47
14	.34584	859	130	829	46
15	612	892	106	819	45
16	639	925	082	809	44
17	666	958	058	799	43
18	694	.36991	034	789	42
19	721	.37024	2.7009	779	41
20	748	057	2.6985	.93769	40
21	.34775	090	961	759	39
22	803	123	937	748	38
23	830	157	913	738	37
24	857	190	889	728	36
25	884	223	865	718	35
26	912	.37256	841	708	34
27	939	289	818	698	33
28	966	322	2.6794	688	32
29	.34993	355	770	677	31
30	.35021	388	746	.93667	30
31	048	422	723	657	29
32	075	455	699	647	28
33	102	.37488	675	637	27
34	130	521	652	626	26
35	157	554	628	616	25
36	184	588	2.6605	606	24
37	.35211	621	581	596	23
38	239	654	558	585	22
39	266	687	534	575	21
40	293	.37720	511	.93565	20
41	320	754	488	555	19
42	347	787	464	544	18
43	375	820	441	534	17
44	.35402	853	2.6418	524	16
45	429	887	395	514	15
46	456	920	371	503	14
47	484	953	348	493	13
48	511	.37986	325	483	12
49	538	.38020	302	472	11
50	565	053	279	.93462	10
51	.35592	086	256	452	9
52	619	120	2.6233	441	8
53	647	153	210	431	7
54	674	186	187	420	6
55	701	220	165	410	5
56	728	253	142	400	4
57	755	286	119	389	3
58	782	320	096	379	2
59	810	353	074	368	1
60	.35837	.38386	2.6051	.93358	0
	cos	cot	tan	sin	′

′	sin	tan	cot	cos	
0	.35837	.38386	2.6051	.93358	60
1	864	420	028	348	59
2	891	453	2.6006	337	58
3	918	487	2.5983	327	57
4	945	520	961	316	56
5	.35973	553	938	306	55
6	.36000	587	916	295	54
7	027	620	893	285	53
8	054	654	871	.93274	52
9	081	.38687	848	264	51
10	108	721	826	253	50
11	135	754	2.5804	243	49
12	162	787	782	232	48
13	190	821	759	222	47
14	217	854	737	211	46
15	.36244	888	715	201	45
16	271	921	693	.93190	44
17	298	955	671	180	43
18	325	.38988	2.5649	169	42
19	352	.39022	627	159	41
20	379	055	605	148	40
21	406	089	583	137	39
22	434	122	561	127	38
23	461	156	539	116	37
24	.36488	190	517	106	36
25	515	223	2.5495	.93095	35
26	542	.39257	473	084	34
27	569	290	452	074	33
28	596	324	430	063	32
29	623	357	408	052	31
30	650	391	386	042	30
31	677	425	365	031	29
32	704	458	2.5343	020	28
33	.36731	.39492	322	.93010	27
34	758	526	300	.92999	26
35	785	559	279	988	25
36	812	593	257	978	24
37	839	626	236	967	23
38	867	660	214	956	22
39	894	694	193	945	21
40	921	.39727	2.5172	935	20
41	948	761	150	924	19
42	.36975	795	129	913	18
43	.37002	829	108	.92902	17
44	029	862	086	892	16
45	056	896	065	881	15
46	083	930	044	870	14
47	110	963	023	859	13
48	137	.39997	2.5002	849	12
49	164	.40031	2.4981	838	11
50	191	065	960	827	10
51	218	098	939	816	9
52	.37245	132	918	.92805	8
53	272	166	897	794	7
54	299	200	876	784	6
55	326	234	2.4855	773	5
56	353	267	834	762	4
57	380	301	813	751	3
58	407	335	792	740	2
59	434	369	772	729	1
60	.37461	.40403	2.4751	.92718	0
	cos	cot	tan	sin	′

69° READ UP 68°

TRIGONOMETRIC FUNCTIONS

22° READ DOWN 23°

′	sin	tan	cot	cos	
0	.37461	.40403	2.4751	.92718	60
1	488	436	730	707	59
2	515	470	709	697	58
3	542	504	689	686	57
4	569	538	668	675	56
5	595	572	648	664	55
6	622	606	627	653	54
7	649	640	606	642	53
8	676	674	586	631	52
9	703	.40707	2.4566	620	51
10	.37730	741	545	.92609	50
11	757	775	525	598	49
12	784	809	504	587	48
13	811	843	484	576	47
14	838	877	464	565	46
15	865	911	443	554	45
16	892	945	423	543	44
17	919	.40979	403	532	43
18	946	.41013	2.4383	521	42
19	973	047	362	510	41
20	.37999	081	342	.92499	40
21	.38026	115	322	488	39
22	053	149	302	477	38
23	080	183	282	466	37
24	107	217	262	455	36
25	134	.41251	242	444	35
26	161	285	222	432	34
27	188	319	2.4202	421	33
28	215	353	182	410	32
29	241	387	162	399	31
30	.38268	421	142	.92388	30
31	295	455	122	377	29
32	322	.41490	102	366	28
33	349	524	083	355	27
34	376	558	063	343	26
35	403	592	043	332	25
36	430	626	023	321	24
37	456	660	2.4004	310	23
38	483	694	2.3984	299	22
39	.38510	.41728	964	287	21
40	537	763	945	.92276	20
41	564	797	925	265	19
42	591	831	906	254	18
43	617	865	886	243	17
44	644	899	867	231	16
45	671	933	2.3847	220	15
46	698	.41968	828	209	14
47	725	.42002	808	198	13
48	.38752	036	789	186	12
49	778	070	770	175	11
50	805	105	750	.92164	10
51	832	139	731	152	9
52	859	173	2.3712	141	8
53	886	207	693	130	7
54	912	.42242	673	119	6
55	939	276	654	107	5
56	966	310	635	096	4
57	.38993	345	616	085	3
58	.39020	379	597	073	2
59	046	413	578	062	1
60	.39073	.42447	2.3559	.92050	0
	cos	cot	tan	sin	′

′	sin	tan	cot	cos	
0	.39073	.42447	2.3559	.92050	60
1	100	482	539	039	59
2	127	516	520	028	58
3	153	551	501	016	57
4	180	585	483	.92005	56
5	207	619	464	.91994	55
6	234	654	445	982	54
7	260	688	2.3426	971	53
8	287	.42722	407	959	52
9	.39314	757	388	948	51
10	341	791	369	936	50
11	367	826	351	925	49
12	394	860	332	914	48
13	421	894	313	.91902	47
14	448	929	2.3294	891	46
15	474	963	276	879	45
16	501	.42998	257	868	44
17	528	.43032	238	856	43
18	.39555	067	220	845	42
19	581	101	201	833	41
20	608	136	183	822	40
21	635	170	2.3164	.91810	39
22	661	205	146	799	38
23	688	239	127	787	37
24	715	274	109	775	36
25	741	308	090	764	35
26	.39768	.43343	072	752	34
27	795	378	053	741	33
28	822	412	035	729	32
29	848	447	2.3017	.91718	31
30	875	481	2.2998	706	30
31	902	516	980	694	29
32	928	550	962	683	28
33	955	585	944	671	27
34	.39982	620	925	660	26
35	.40008	.43654	907	648	25
36	035	689	889	636	24
37	062	724	2.2871	.91625	23
38	088	758	853	613	22
39	115	793	835	601	21
40	141	828	817	590	20
41	168	862	799	578	19
42	195	897	781	566	18
43	.40221	932	763	555	17
44	248	.43966	745	543	16
45	275	.44001	2.2727	.91531	15
46	301	036	709	519	14
47	328	071	691	508	13
48	355	105	673	496	12
49	381	140	655	484	11
50	408	175	637	472	10
51	.40434	210	620	461	9
52	461	.44244	2.2602	.91449	8
53	488	279	584	437	7
54	514	314	566	425	6
55	541	349	549	414	5
56	567	384	531	402	4
57	594	418	513	390	3
58	621	453	496	378	2
59	647	488	478	366	1
60	.40674	.44523	2.2460	.91355	0
	cos	cot	tan	sin	′

67° READ UP 66°

TRIGONOMETRIC FUNCTIONS

24° READ DOWN 25°

24°

'	sin	tan	cot	cos	
0	.40674	.44523	2.2460	.91355	60
1	700	558	443	343	59
2	727	593	425	331	58
3	753	627	408	319	57
4	780	662	390	307	56
5	806	697	373	295	55
6	.40833	732	355	283	54
7	860	.44767	338	.91272	53
8	886	802	320	260	52
9	913	837	2.2303	248	51
10	939	872	286	236	50
11	966	907	268	224	49
12	.40992	942	251	212	48
13	.41019	.44977	234	200	47
14	045	.45012	216	188	46
15	072	047	199	.91176	45
16	098	082	182	164	44
17	125	117	2.2165	152	43
18	151	152	148	140	42
19	178	187	130	128	41
20	204	222	113	116	40
21	231	.45257	096	104	39
22	.41257	292	079	.91092	38
23	284	327	062	080	37
24	310	362	045	068	36
25	337	397	028	056	35
26	363	432	2.2011	044	34
27	390	467	2.1994	032	33
28	416	.45502	977	020	32
29	443	538	960	.91008	31
30	469	573	943	.90996	30
31	.41496	608	926	984	29
32	522	643	909	972	28
33	549	678	892	960	27
34	575	713	876	948	26
35	602	.45748	2.1859	936	25
36	628	784	842	924	24
37	655	819	825	.90911	23
38	681	854	808	899	22
39	707	889	792	887	21
40	.41734	924	775	875	20
41	760	960	758	863	19
42	787	.45995	742	851	18
43	813	.46030	2.1725	839	17
44	840	065	708	826	16
45	866	101	692	814	15
46	892	136	675	.90802	14
47	919	171	659	790	13
48	945	206	642	778	12
49	972	242	625	766	11
50	.41998	277	609	753	10
51	.42024	312	592	741	9
52	051	.46348	2.1576	729	8
53	077	383	560	.90717	7
54	104	418	543	704	6
55	130	454	527	692	5
56	156	489	510	680	4
57	183	525	494	668	3
58	209	560	478	655	2
59	235	595	461	643	1
60	.42262	.46631	2.1445	.90631	0
	cos	cot	tan	sin	'

25°

'	sin	tan	cot	cos	
0	.42262	.46631	2.1445	.90631	60
1	288	666	429	618	59
2	315	702	413	606	58
3	341	737	396	594	57
4	367	772	380	582	56
5	394	808	364	569	55
6	420	843	348	557	54
7	.42446	879	332	545	53
8	473	914	315	532	52
9	499	950	2.1299	520	51
10	525	.46985	283	.90507	50
11	552	.47021	267	495	49
12	578	056	251	483	48
13	604	092	235	470	47
14	.42631	128	219	458	46
15	657	163	203	446	45
16	683	199	187	433	44
17	709	234	171	421	43
18	736	270	2.1155	408	42
19	762	305	139	396	41
20	788	.47341	123	.90383	40
21	.42815	377	107	371	39
22	841	412	092	358	38
23	867	448	076	346	37
24	894	483	060	334	36
25	920	519	044	321	35
26	946	555	028	309	34
27	972	590	2.1013	296	33
28	.42999	626	2.0997	284	32
29	.43025	.47662	981	271	31
30	051	698	965	.90259	30
31	077	733	950	246	29
32	104	769	934	233	28
33	130	805	918	221	27
34	156	840	903	208	26
35	182	876	887	196	25
36	209	912	2.0872	183	24
37	.43235	948	856	171	23
38	261	.47984	840	158	22
39	287	.48019	825	146	21
40	313	055	809	.90133	20
41	340	091	794	120	19
42	366	127	778	108	18
43	392	163	763	095	17
44	.43418	198	2.0748	082	16
45	445	234	732	070	15
46	471	.48270	717	057	14
47	497	306	701	045	13
48	523	342	686	032	12
49	549	378	671	019	11
50	575	414	655	.90007	10
51	602	450	640	.89994	9
52	.43628	486	2.0625	981	8
53	654	.48521	609	968	7
54	680	557	594	956	6
55	706	593	579	943	5
56	733	629	564	930	4
57	759	665	549	918	3
58	785	701	533	905	2
59	811	737	518	892	1
60	.43837	.48773	2.0503	.89879	0
	cos	cot	tan	sin	'

65° READ UP 64°

TRIGONOMETRIC FUNCTIONS

26° READ DOWN 27°

′	sin	tan	cot	cos	
0	.43837	.48773	2.0503	.89879	60
1	863	809	488	867	59
2	889	845	473	854	58
3	916	881	458	841	57
4	942	917	443	828	56
5	968	953	428	816	55
6	.43994	.48989	413	803	54
7	.44020	.49026	398	790	53
8	046	062	2.0383	777	52
9	072	098	368	764	51
10	098	134	353	.89752	50
11	124	170	338	739	49
12	151	206	323	726	48
13	177	242	308	713	47
14	203	278	293	700	46
15	.44229	.49315	2.0278	687	45
16	255	351	263	674	44
17	281	387	248	662	43
18	307	423	233	649	42
19	333	459	219	636	41
20	359	495	204	.89623	40
21	385	532	189	610	39
22	.44411	568	174	597	38
23	437	604	160	584	37
24	464	.49640	2.0145	571	36
25	490	677	130	558	35
26	516	713	115	545	34
27	542	749	101	532	33
28	568	786	086	519	32
29	.44594	822	072	506	31
30	620	858	057	.89493	30
31	646	894	042	480	29
32	672	931	028	467	28
33	698	.49967	2.0013	454	27
34	724	.50004	1.9999	441	26
35	750	040	984	428	25
36	.44776	076	970	415	24
37	802	113	955	402	23
38	828	149	941	389	22
39	854	185	926	376	21
40	880	222	912	.89363	20
41	906	258	897	350	19
42	932	295	883	337	18
43	958	.50331	1.9868	324	17
44	.44984	368	854	311	16
45	.45010	404	840	298	15
46	036	441	825	285	14
47	062	477	811	272	13
48	088	514	797	259	12
49	114	550	782	245	11
50	140	587	768	.89232	10
51	166	623	754	219	9
52	.45192	.50660	1.9740	206	8
53	218	696	725	193	7
54	243	733	711	180	6
55	269	769	697	167	5
56	295	806	683	153	4
57	321	843	669	140	3
58	347	879	654	127	2
59	373	916	640	114	1
60	.45399	.50953	1.9626	.89101	0
	cos	cot	tan	sin	′

′	sin	tan	cot	cos	
0	.45399	.50953	1.9626	.89101	60
1	425	.50989	612	087	59
2	451	.51026	598	074	58
3	477	063	584	061	57
4	503	099	570	048	56
5	529	136	556	035	55
6	554	173	542	021	54
7	.45580	209	528	.89008	53
8	606	246	1.9514	.88995	52
9	632	283	500	981	51
10	658	319	486	968	50
11	684	.51356	472	955	49
12	710	393	458	942	48
13	736	430	444	928	47
14	762	467	430	915	46
15	.45787	503	1.9416	902	45
16	813	540	402	.88888	44
17	839	577	388	875	43
18	865	614	375	862	42
19	891	651	361	848	41
20	917	.51688	347	835	40
21	942	724	333	822	39
22	968	761	1.9319	808	38
23	.45994	798	306	795	37
24	.46020	835	292	.88782	36
25	046	872	278	768	35
26	072	909	265	755	34
27	097	946	251	741	33
28	123	.51983	237	728	32
29	149	.52020	1.9223	715	31
30	175	057	210	701	30
31	201	094	196	.88688	29
32	226	131	183	674	28
33	.46252	168	169	661	27
34	278	205	155	647	26
35	304	242	142	634	25
36	330	279	128	620	24
37	355	316	1.9115	607	23
38	381	.52353	101	.88593	22
39	407	390	088	580	21
40	433	427	074	566	20
41	458	464	061	553	19
42	.46484	501	047	539	18
43	510	538	034	526	17
44	536	575	020	512	16
45	561	613	1.9007	.88499	15
46	587	650	1.8993	485	14
47	613	.52687	980	472	13
48	639	724	967	458	12
49	664	761	953	445	11
50	690	798	940	431	10
51	.46716	836	927	417	9
52	742	873	913	404	8
53	767	910	1.8900	.88390	7
54	793	947	887	377	6
55	819	.52985	873	363	5
56	844	.53022	860	349	4
57	870	059	847	336	3
58	896	096	834	322	2
59	921	134	820	308	1
60	.46947	.53171	1.8807	.88295	0
	cos	cot	tan	sin	′

63° READ UP 62°

TRIGONOMETRIC FUNCTIONS

28° READ DOWN

′	sin	tan	cot	cos	
0	.46947	.53171	1.8807	.88295	60
1	973	208	794	281	59
2	.46999	246	781	267	58
3	.47024	283	768	254	57
4	050	320	755	240	56
5	076	358	741	226	55
6	101	395	728	213	54
7	127	.53432	715	.88199	53
8	153	470	702	185	52
9	178	507	689	172	51
10	.47204	545	1.8676	158	50
11	229	582	663	144	49
12	255	620	650	130	48
13	281	657	637	117	47
14	306	694	624	.88103	46
15	332	.53732	611	089	45
16	358	769	598	075	44
17	383	807	585	062	43
18	.47409	844	572	048	42
19	434	882	559	034	41
20	460	920	1.8546	020	40
21	486	957	533	.88006	39
22	511	.53995	520	.87993	38
23	537	.54032	507	979	37
24	562	070	495	965	36
25	588	107	482	951	35
26	.47614	145	469	937	34
27	639	183	456	923	33
28	665	220	443	909	32
29	690	258	430	896	31
30	716	296	1.8418	.87882	30
31	741	.54333	405	868	29
32	767	371	392	854	28
33	793	409	379	840	27
34	.47818	446	367	826	26
35	844	484	354	812	25
36	869	522	341	798	24
37	895	560	329	.87784	23
38	920	597	316	770	22
39	946	635	303	756	21
40	971	.54673	1.8291	743	20
41	.47997	711	278	729	19
42	.48022	748	265	715	18
43	048	786	253	701	17
44	073	824	240	687	16
45	099	862	228	.87673	15
46	124	900	215	659	14
47	150	938	202	645	13
48	175	.54975	190	631	12
49	201	.55013	177	617	11
50	226	051	1.8165	603	10
51	.48252	089	152	589	9
52	277	127	140	.87575	8
53	303	165	127	561	7
54	328	203	115	546	6
55	354	241	103	532	5
56	379	279	090	518	4
57	405	317	078	504	3
58	430	355	065	490	2
59	456	393	053	476	1
60	.48481	.55431	1.8040	.87462	0
	cos	cot	tan	sin	′

61° READ UP

29° READ DOWN

′	sin	tan	cot	cos	
0	.48481	.55431	1.8040	.87462	60
1	506	469	028	448	59
2	532	507	016	434	58
3	557	545	1.8003	420	57
4	583	583	1.7991	406	56
5	608	621	979	391	55
6	634	659	966	377	54
7	659	.55697	954	363	53
8	684	736	942	.87349	52
9	710	774	930	335	51
10	.48735	812	917	321	50
11	761	850	905	306	49
12	786	888	1.7893	292	48
13	811	926	881	278	47
14	837	.55964	868	264	46
15	862	.56003	856	250	45
16	888	041	844	.87235	44
17	913	079	832	221	43
18	938	117	820	207	42
19	964	156	808	193	41
20	.48989	194	1.7796	178	40
21	.49014	232	783	164	39
22	040	270	771	150	38
23	065	.56309	759	136	37
24	090	347	747	.87121	36
25	116	385	735	107	35
26	141	424	723	093	34
27	166	462	711	079	33
28	.49192	501	1.7699	064	32
29	217	539	687	050	31
30	242	.56577	675	036	30
31	268	616	663	021	29
32	293	654	651	.87007	28
33	318	693	639	.86993	27
34	344	731	627	978	26
35	369	769	615	964	25
36	.49394	808	1.7603	949	24
37	419	846	591	935	23
38	445	885	579	921	22
39	470	923	567	906	21
40	495	.56962	556	892	20
41	521	.57000	544	878	19
42	546	039	532	.86863	18
43	571	078	520	849	17
44	.49596	116	1.7508	834	16
45	622	155	496	820	15
46	647	193	485	805	14
47	672	232	473	791	13
48	697	271	461	777	12
49	723	309	449	762	11
50	748	.57348	437	748	10
51	773	386	426	.86733	9
52	.49798	425	1.7414	719	8
53	824	464	402	704	7
54	849	503	391	690	6
55	874	541	379	675	5
56	899	580	367	661	4
57	924	619	355	646	3
58	950	657	344	632	2
59	.49975	696	332	617	1
60	.50000	.57735	1.7321	.86603	0
	cos	cot	tan	sin	′

60° READ UP

TRIGONOMETRIC FUNCTIONS

30° READ DOWN

′	sin	tan	cot	cos	
0	.50000	.57735	1.7321	.86603	60
1	025	774	309	588	59
2	050	813	297	573	58
3	076	851	286	559	57
4	101	890	274	544	56
5	126	929	262	530	55
6	151	.57968	251	515	54
7	176	.58007	239	501	53
8	201	046	228	.86486	52
9	227	085	1.7216	471	51
10	.50252	124	205	457	50
11	277	162	193	442	49
12	302	201	182	427	48
13	327	240	170	413	47
14	352	279	159	398	46
15	377	.58318	147	384	45
16	403	357	136	.86369	44
17	428	396	124	354	43
18	453	435	1.7113	340	42
19	478	474	102	325	41
20	.50503	513	090	310	40
21	528	552	079	295	39
22	553	591	067	281	38
23	578	631	056	266	37
24	603	.58670	045	.86251	36
25	628	709	033	237	35
26	654	748	022	222	34
27	679	787	1.7011	207	33
28	704	826	1.6999	192	32
29	729	865	988	178	31
30	.50754	905	977	163	30
31	779	944	965	148	29
32	804	.58983	954	.86133	28
33	829	.59022	943	119	27
34	854	061	932	104	26
35	879	101	920	089	25
36	904	140	1.6909	074	24
37	929	179	898	059	23
38	954	218	887	045	22
39	.50979	258	875	030	21
40	.51004	297	864	015	20
41	029	.59336	853	.86000	19
42	054	376	842	.85985	18
43	079	415	831	970	17
44	104	454	1.6820	956	16
45	129	494	808	941	15
46	154	533	797	926	14
47	179	573	786	911	13
48	204	612	775	896	12
49	229	.59651	764	881	11
50	.51254	691	753	866	10
51	279	730	742	.85851	9
52	304	770	1.6731	836	8
53	329	809	720	821	7
54	354	849	709	806	6
55	379	888	698	792	5
56	404	928	687	777	4
57	429	.59967	676	762	3
58	454	.60007	665	747	2
59	479	046	654	732	1
60	.51504	.60086	1.6643	.85717	0
	cos	cot	tan	sin	′

59° READ UP

31° READ DOWN

′	sin	tan	cot	cos	
0	.51504	.60086	1.6643	.85717	60
1	529	126	632	702	59
2	554	165	621	687	58
3	579	205	610	672	57
4	604	245	599	657	56
5	628	284	588	642	55
6	653	324	577	627	54
7	678	.60364	566	.85612	53
8	703	403	555	597	52
9	.51728	443	545	582	51
10	753	483	1.6534	567	50
11	778	522	523	551	49
12	803	562	512	536	48
13	828	602	501	521	47
14	852	642	490	506	46
15	877	.60681	479	.85491	45
16	902	721	469	476	44
17	927	761	458	461	43
18	952	801	447	446	42
19	.51977	841	436	431	41
20	.52002	881	1.6426	416	40
21	026	921	415	401	39
22	051	.60960	404	385	38
23	076	.61000	393	.85370	37
24	101	040	383	355	36
25	126	080	372	340	35
26	151	120	361	325	34
27	175	160	351	310	33
28	.52200	200	340	294	32
29	225	240	329	279	31
30	250	280	1.6319	264	30
31	275	.61320	308	.85249	29
32	299	360	297	234	28
33	324	400	287	218	27
34	349	440	276	203	26
35	374	480	265	188	25
36	.52399	520	255	173	24
37	423	561	244	157	23
38	448	601	234	142	22
39	473	.61641	223	.85127	21
40	498	681	1.6212	112	20
41	522	721	202	096	19
42	547	761	191	081	18
43	572	801	181	066	17
44	.52597	842	170	051	16
45	621	882	160	035	15
46	646	922	149	020	14
47	671	.61962	139	.85005	13
48	696	.62003	128	.84989	12
49	720	043	118	974	11
50	745	083	1.6107	959	10
51	.52770	124	097	943	9
52	794	164	087	928	8
53	819	204	076	913	7
54	844	.62245	066	.84897	6
55	869	285	055	882	5
56	893	325	045	866	4
57	918	366	034	851	3
58	943	406	024	836	2
59	967	446	014	820	1
60	.52992	.62487	1.6003	.84805	0
	cos	cot	tan	sin	′

58° READ UP

TRIGONOMETRIC FUNCTIONS

32° READ DOWN 33°

′	sin	tan	cot	cos	
0	.52992	.62487	1.6003	.84805	60
1	.53017	527	1.5993	789	59
2	041	568	983	774	58
3	066	608	972	759	57
4	091	649	962	743	56
5	115	689	952	728	55
6	140	.62730	941	712	54
7	164	770	931	697	53
8	189	811	921	.84681	52
9	.53214	852	911	666	51
10	238	892	1.5900	650	50
11	263	933	890	635	49
12	288	.62973	880	619	48
13	312	.63014	869	604	47
14	337	055	859	588	46
15	361	095	849	.84573	45
16	.53386	136	839	557	44
17	411	177	829	542	43
18	435	217	818	526	42
19	460	258	808	511	41
20	484	299	1.5798	495	40
21	509	.63340	788	480	39
22	534	380	778	464	38
23	558	421	768	.84448	37
24	.53583	462	757	433	36
25	607	503	747	417	35
26	632	544	737	402	34
27	656	584	727	386	33
28	681	625	717	370	32
29	705	.63666	707	355	31
30	730	707	1.5697	.84339	30
31	754	748	687	324	29
32	.53779	789	677	308	28
33	804	830	667	292	27
34	828	871	657	277	26
35	853	912	647	261	25
36	877	953	637	245	24
37	902	.63994	627	230	23
38	926	.64035	617	.84214	22
39	951	076	607	198	21
40	.53975	117	1.5597	182	20
41	.54000	158	587	167	19
42	024	199	577	151	18
43	049	240	567	135	17
44	073	281	557	120	16
45	097	.64322	547	.84104	15
46	122	363	537	088	14
47	146	404	527	072	13
48	171	446	517	057	12
49	195	487	507	041	11
50	54220	528	1.5497	025	10
51	244	569	487	.84009	9
52	269	.64610	477	.83994	8
53	293	652	468	978	7
54	317	693	458	962	6
55	342	734	448	946	5
56	366	775	438	930	4
57	391	817	428	915	3
58	415	858	418	899	2
59	440	899	408	883	1
60	.54464	.64941	1.5399	.83867	0
	cos	cot	tan	sin	′

′	sin	tan	cot	cos	
0	.54464	.64941	1.5399	.83867	60
1	488	.64982	389	851	59
2	513	.65024	379	835	58
3	537	065	369	819	57
4	561	106	359	804	56
5	586	148	350	788	55
6	610	189	340	772	54
7	.54635	231	330	.83756	53
8	659	272	1.5320	740	52
9	683	.65314	311	724	51
10	708	355	301	708	50
11	732	397	291	692	49
12	756	438	282	676	48
13	781	480	272	660	47
14	805	521	262	645	46
15	.54829	563	253	.83629	45
16	854	604	1.5243	613	44
17	878	.65646	233	597	43
18	902	688	224	581	42
19	927	729	214	565	41
20	951	771	204	549	40
21	975	813	195	533	39
22	.54999	854	185	517	38
23	.55024	896	175	.83501	37
24	048	938	1.5166	485	36
25	072	.65980	156	469	35
26	097	.66021	147	453	34
27	121	063	137	437	33
28	145	105	127	421	32
29	169	147	118	405	31
30	.55194	189	108	389	30
31	218	230	099	.83373	29
32	242	272	1.5089	356	28
33	266	314	080	340	27
34	291	.66356	070	324	26
35	315	398	061	308	25
36	339	440	051	292	24
37	55363	482	042	276	23
38	388	524	032	260	22
39	412	566	023	.83244	21
40	436	608	013	228	20
41	460	.66650	1.5004	212	19
42	484	692	1.4994	195	18
43	509	734	985	179	17
44	533	776	975	163	16
45	.55557	818	966	147	15
46	581	860	957	131	14
47	605	902	947	.83115	13
48	630	944	938	098	12
49	654	.66986	928	082	11
50	678	.67028	919	066	10
51	702	071	1.4910	050	9
52	.55726	113	900	034	8
53	750	155	891	017	7
54	775	197	882	.83001	6
55	799	239	872	.82985	5
56	823	282	863	969	4
57	847	324	854	953	3
58	871	366	844	936	2
59	895	409	835	920	1
60	.55919	.67451	1.4826	.82904	0
	cos	cot	tan	sin	′

57° READ UP 56°

TRIGONOMETRIC FUNCTIONS

34° READ DOWN 35°

′	sin	tan	cot	cos	
0	.55919	.67451	1.4826	.82904	60
1	943	493	816	887	59
2	968	536	807	871	58
3	.55992	578	798	855	57
4	.56016	620	788	839	56
5	040	663	779	822	55
6	064	.67705	770	806	54
7	088	748	761	790	53
8	112	790	751	773	52
9	136	832	742	.82757	51
10	160	875	1.4733	741	50
11	184	917	724	724	49
12	.56208	.67960	715	708	48
13	232	.68002	705	692	47
14	256	045	696	675	46
15	280	088	687	659	45
16	305	130	678	643	44
17	329	173	669	626	43
18	353	215	659	.82610	42
19	377	258	650	593	41
20	.56401	301	1.4641	577	40
21	425	.68343	632	561	39
22	449	386	623	544	38
23	473	429	614	528	37
24	497	471	605	511	36
25	521	514	596	495	35
26	545	557	586	478	34
27	569	600	577	.82462	33
28	.56593	.68642	568	446	32
29	617	685	559	429	31
30	641	728	1.4550	413	30
31	665	771	541	396	29
32	689	814	532	380	28
33	713	857	523	363	27
34	736	900	514	347	26
35	760	942	505	330	25
36	.56784	.68985	496	.82314	24
37	808	.69028	487	297	23
38	832	071	478	281	22
39	856	114	469	264	21
40	880	157	1.4460	248	20
41	904	200	451	231	19
42	928	243	442	214	18
43	952	286	433	198	17
44	.56976	.69329	424	181	16
45	.57000	372	415	165	15
46	024	416	406	.82148	14
47	047	459	397	132	13
48	071	502	388	115	12
49	095	545	379	098	11
50	119	588	1.4370	082	10
51	143	631	361	065	9
52	167	.69675	352	048	8
53	.57191	718	344	032	7
54	215	761	335	.82015	6
55	238	804	326	.81999	5
56	262	847	317	982	4
57	286	891	308	965	3
58	310	934	299	949	2
59	334	.69977	290	932	1
60	.57358	.70021	1.4281	.81915	0
	cos	cot	tan	sin	′

′	sin	tan	cot	cos	
0	.57358	.70021	1.4281	.81915	60
1	381	064	273	899	59
2	405	107	264	882	58
3	429	151	255	865	57
4	453	194	246	848	56
5	477	238	237	832	55
6	501	281	229	815	54
7	524	.70325	220	.81798	53
8	548	368	1.4211	782	52
9	.57572	412	202	765	51
10	596	455	193	748	50
11	619	499	185	731	49
12	643	542	176	714	48
13	667	586	167	698	47
14	691	629	158	681	46
15	715	.70673	150	.81664	45
16	738	717	1.4141	647	44
17	762	760	132	631	43
18	.57786	804	124	614	42
19	810	848	115	597	41
20	833	891	106	580	40
21	857	935	097	563	39
22	881	.70979	089	546	38
23	904	.71023	080	.81530	37
24	928	066	1.4071	513	36
25	952	110	063	496	35
26	976	154	054	479	34
27	.57999	198	045	462	33
28	.58023	242	037	445	32
29	047	285	028	428	31
30	070	.71329	019	412	30
31	094	373	011	.81395	29
32	118	417	1.4002	378	28
33	141	461	1.3994	361	27
34	165	505	985	344	26
35	189	549	976	327	25
36	.58212	593	968	310	24
37	236	637	959	293	23
38	260	.71681	951	276	22
39	283	725	942	.81259	21
40	307	769	934	242	20
41	330	813	925	225	19
42	354	857	1.3916	208	18
43	378	901	908	191	17
44	.58401	946	899	174	16
45	425	.71990	891	157	15
46	449	.72034	882	140	14
47	472	078	874	.81123	13
48	496	122	865	106	12
49	519	167	857	089	11
50	543	211	848	072	10
51	567	255	1.3840	055	9
52	.58590	299	831	038	8
53	614	.72344	823	021	7
54	637	388	814	.81004	6
55	661	432	806	.80987	5
56	684	477	798	970	4
57	708	521	789	953	3
58	731	565	781	936	2
59	755	610	772	919	1
60	.58779	.72654	1.3764	.80902	0
	cos	cot	tan	sin	′

55° READ UP 54°

TRIGONOMETRIC FUNCTIONS

36° READ DOWN 37°

′	sin	tan	cot	cos	
0	.58779	.72654	1.3764	.80902	60
1	802	699	755	885	59
2	826	743	747	867	58
3	849	788	739	850	57
4	873	832	730	833	56
5	896	877	722	816	55
6	920	921	713	799	54
7	943	.72966	705	.80782	53
8	967	.73010	697	765	52
9	.58990	055	688	748	51
10	.59014	100	1.3680	730	50
11	037	144	672	713	49
12	061	189	663	696	48
13	084	234	655	679	47
14	108	278	647	662	46
15	131	.73323	638	.80644	45
16	154	368	630	627	44
17	178	413	622	610	43
18	201	457	613	593	42
19	.59225	502	605	576	41
20	248	547	1.3597	558	40
21	272	592	588	541	39
22	295	.73637	580	.80524	38
23	318	681	572	507	37
24	342	726	564	489	36
25	365	771	555	472	35
26	389	816	547	455	34
27	.59412	861	539	438	33
28	436	906	531	420	32
29	459	951	522	403	31
30	482	.73996	1.3514	.80386	30
31	506	.74041	506	368	29
32	529	086	498	351	28
33	552	131	490	334	27
34	576	176	481	316	26
35	.59599	221	473	299	25
36	622	267	465	282	24
37	646	312	457	.80264	23
38	669	.74357	449	247	22
39	693	402	440	230	21
40	716	447	1.3432	212	20
41	739	492	424	195	19
42	763	538	416	178	18
43	.59786	583	408	160	17
44	809	628	400	143	16
45	832	.74674	392	.80125	15
46	856	719	384	108	14
47	879	764	375	091	13
48	902	810	367	073	12
49	926	855	359	056	11
50	949	900	1.3351	038	10
51	972	946	343	021	9
52	.59995	.74991	335	.80003	8
53	.60019	.75037	327	.79986	7
54	042	082	319	968	6
55	065	128	311	951	5
56	089	173	303	934	4
57	112	219	295	916	3
58	135	264	287	899	2
59	158	310	278	881	1
60	.60182	.75355	1.3270	.79864	0
	cos	cot	tan	sin	′

′	sin	tan	cot	cos	
0	.60182	.75355	1.3270	.79864	60
1	205	401	262	846	59
2	228	447	254	829	58
3	251	492	246	811	57
4	274	538	238	793	56
5	298	584	230	776	55
6	321	629	222	758	54
7	344	.75675	214	741	53
8	367	721	206	723	52
9	.60390	767	1.3198	706	51
10	414	812	190	.79688	50
11	437	858	182	671	49
12	460	904	175	653	48
13	483	950	167	635	47
14	506	.75996	159	618	46
15	529	.76042	151	600	45
16	553	088	143	583	44
17	.60576	134	1.3135	565	43
18	599	180	127	547	42
19	622	226	119	530	41
20	645	272	111	.79512	40
21	668	318	103	494	39
22	691	364	095	477	38
23	714	410	087	459	37
24	738	456	079	441	36
25	761	.76502	072	424	35
26	.60784	548	1.3064	406	34
27	807	594	056	388	33
28	830	640	048	371	32
29	853	686	040	353	31
30	876	733	032	.79335	30
31	899	779	024	318	29
32	922	825	017	300	28
33	945	871	009	282	27
34	968	918	1.3001	264	26
35	.60991	.76964	1.2993	247	25
36	.61015	.77010	985	229	24
37	038	057	977	211	23
38	061	103	970	193	22
39	084	149	962	176	21
40	107	196	954	.79158	20
41	130	242	946	140	19
42	153	289	938	122	18
43	176	.77335	1.2931	105	17
44	.61199	382	923	087	16
45	222	428	915	069	15
46	245	475	907	051	14
47	268	521	900	033	13
48	291	568	892	.79016	12
49	314	615	884	.78998	11
50	337	.77661	876	980	10
51	360	708	869	962	9
52	.61383	754	1.2861	944	8
53	406	801	853	926	7
54	429	848	846	908	6
55	451	895	838	891	5
56	474	941	830	873	4
57	497	.77988	822	855	3
58	520	.78035	815	837	2
59	543	082	807	819	1
60	.61566	.78129	1.2799	.78801	0
	cos	cot	tan	sin	′

53° READ UP 52°

TRIGONOMETRIC FUNCTIONS

38° READ DOWN 39°

'	sin	tan	cot	cos	
0	.61566	.78129	1.2799	.78801	60
1	589	175	792	783	59
2	612	222	784	765	58
3	635	269	776	747	57
4	658	316	769	729	56
5	681	363	761	711	55
6	704	410	753	694	54
7	726	457	746	676	53
8	749	504	738	.78658	52
9	.61772	.78551	731	640	51
10	795	598	1.2723	622	50
11	818	645	715	604	49
12	841	692	708	586	48
13	864	739	700	568	47
14	887	786	693	550	46
15	909	834	685	.78532	45
16	932	881	677	514	44
17	955	928	670	496	43
18	.61978	.78975	662	478	42
19	.62001	.79022	655	460	41
20	024	070	1.2647	442	40
21	046	117	640	424	39
22	069	164	632	.78405	38
23	092	212	624	387	37
24	115	259	617	369	36
25	138	306	609	351	35
26	160	354	602	333	34
27	.62183	401	594	315	33
28	206	449	587	297	32
29	229	.79496	579	.78279	31
30	251	544	1.2572	261	30
31	274	591	564	243	29
32	297	639	557	225	28
33	320	686	549	206	27
34	342	734	542	188	26
35	.62365	781	534	170	25
36	388	829	527	.78152	24
37	411	877	519	134	23
38	433	924	512	116	22
39	456	.79972	504	098	21
40	479	.80020	1.2497	079	20
41	502	067	489	061	19
42	524	115	482	043	18
43	547	163	475	025	17
44	.62570	211	467	.78007	16
45	592	258	460	.77988	15
46	615	306	452	970	14
47	638	354	445	952	13
48	660	402	437	934	12
49	683	450	430	916	11
50	706	.80498	1.2423	897	10
51	728	546	415	879	9
52	.62751	594	408	.77861	8
53	774	642	401	843	7
54	796	690	393	824	6
55	819	738	386	806	5
56	842	786	378	788	4
57	864	834	371	769	3
58	887	882	364	751	2
59	909	930	356	733	1
60	.62932	.80978	1.2349	.77715	0
	cos	cot	tan	sin	'

'	sin	tan	cot	cos	
0	.62932	.80978	1.2349	.77715	60
1	955	.81027	342	696	59
2	.62977	075	334	678	58
3	.63000	123	327	660	57
4	022	171	320	641	56
5	045	220	312	623	55
6	068	268	305	605	54
7	090	316	298	586	53
8	113	364	290	.77568	52
9	135	413	283	550	51
10	.63158	461	1.2276	531	50
11	180	.81510	268	513	49
12	203	558	261	494	48
13	225	606	254	476	47
14	248	655	247	458	46
15	271	703	239	439	45
16	293	752	232	.77421	44
17	.63316	800	225	402	43
18	338	849	218	384	42
19	361	898	210	366	41
20	383	946	1.2203	347	40
21	406	.81995	196	329	39
22	428	.82044	189	310	38
23	451	092	181	.77292	37
24	.63473	141	174	273	36
25	496	190	167	255	35
26	518	238	160	236	34
27	540	287	153	218	33
28	563	336	145	199	32
29	585	385	138	181	31
30	608	434	1.2131	.77162	30
31	.63630	.82483	124	144	29
32	653	531	117	125	28
33	675	580	109	107	27
34	698	629	102	088	26
35	720	678	095	070	25
36	742	727	088	051	24
37	765	776	081	033	23
38	787	825	074	.77014	22
39	.63810	874	066	.76996	21
40	832	923	1.2059	977	20
41	854	.82972	052	959	19
42	877	.83022	045	940	18
43	899	071	038	921	17
44	922	120	031	903	16
45	944	169	024	884	15
46	966	218	017	.76866	14
47	.63989	268	009	847	13
48	.64011	317	1.2002	828	12
49	033	366	1.1995	810	11
50	056	415	988	791	10
51	078	.83465	981	772	9
52	100	514	974	754	8
53	123	564	967	.76735	7
54	.64145	613	960	717	6
55	167	662	953	698	5
56	190	712	946	679	4
57	212	761	939	661	3
58	234	811	932	642	2
59	256	860	925	623	1
60	.64279	.83910	1.1918	.76604	0
	cos	cot	tan	sin	'

51° READ UP 50°

TRIGONOMETRIC FUNCTIONS

40° READ DOWN 41°

'	sin	tan	cot	cos	
0	.64279	.83910	1.1918	.76604	60
1	301	.83960	910	586	59
2	323	.84009	903	567	58
3	346	059	896	548	57
4	368	108	889	530	56
5	390	158	882	511	55
6	412	208	875	492	54
7	435	258	868	473	53
8	.64457	307	861	.76455	52
9	479	357	854	436	51
10	501	407	1.1847	417	50
11	524	.84457	840	398	49
12	546	507	833	380	48
13	568	556	826	361	47
14	590	606	819	342	46
15	612	656	812	323	45
16	.64635	706	806	.76304	44
17	657	756	799	286	43
18	679	806	792	267	42
19	701	856	785	248	41
20	723	906	1.1778	229	40
21	746	.84956	771	210	39
22	768	.85006	764	192	38
23	790	057	757	173	37
24	.64812	107	750	.76154	36
25	834	157	743	135	35
26	856	207	736	116	34
27	878	257	729	097	33
28	901	308	722	078	32
29	923	358	715	059	31
30	945	408	1.1708	041	30
31	967	.85458	702	022	29
32	.64989	509	695	.76003	28
33	.65011	559	688	.75984	27
34	033	609	681	965	26
35	055	660	674	946	25
36	077	710	667	927	24
37	100	761	660	908	23
38	122	811	653	889	22
39	144	862	647	870	21
40	166	912	1.1640	851	20
41	188	.85963	633	832	19
42	.65210	.86014	626	.75813	18
43	232	064	619	794	17
44	254	115	612	775	16
45	276	166	606	756	15
46	298	216	599	738	14
47	320	267	592	719	13
48	342	318	585	700	12
49	364	368	578	680	11
50	.65386	419	1.1571	661	10
51	408	.86470	565	.75642	9
52	430	521	558	623	8
53	452	572	551	604	7
54	474	623	544	585	6
55	496	674	538	566	5
56	518	725	531	547	4
57	540	776	524	528	3
58	562	827	517	509	2
59	584	878	510	490	1
60	.65606	.86929	1.1504	.75471	0
	cos	cot	tan	sin	'

'	sin	tan	cot	cos	
0	.65606	.86929	1.1504	.75471	60
1	628	.86980	497	452	59
2	650	.87031	490	433	58
3	672	082	483	414	57
4	694	133	477	395	56
5	716	184	470	375	55
6	738	236	463	356	54
7	759	287	456	337	53
8	781	338	450	.75318	52
9	.65803	389	443	299	51
10	825	441	1.1436	280	50
11	847	.87492	430	261	49
12	869	543	423	241	48
13	891	595	416	222	47
14	913	646	410	203	46
15	935	698	403	184	45
16	956	749	396	.75165	44
17	.65978	801	389	146	43
18	.66000	852	383	126	42
19	022	904	376	107	41
20	044	.87955	1.1369	088	40
21	066	.88007	363	069	39
22	088	059	356	050	38
23	109	110	349	030	37
24	131	162	343	.75011	36
25	.66153	214	336	.74992	35
26	175	265	329	973	34
27	197	317	323	953	33
28	218	369	316	934	32
29	240	421	310	915	31
30	262	.88473	1.1303	896	30
31	284	524	296	876	29
32	.66306	576	290	857	28
33	327	628	283	838	27
34	349	680	276	.74818	26
35	371	732	270	799	25
36	393	784	263	780	24
37	414	836	257	760	23
38	436	888	250	741	22
39	.66458	940	243	722	21
40	480	.88992	1.1237	703	20
41	501	.89045	230	683	19
42	523	097	224	664	18
43	545	149	217	.74644	17
44	566	201	211	625	16
45	588	253	204	606	15
46	66610	306	197	586	14
47	632	358	191	567	13
48	653	410	184	548	12
49	675	463	178	528	11
50	697	.89515	1.1171	509	10
51	718	567	165	.74489	9
52	740	620	158	470	8
53	.66762	672	152	451	7
54	783	725	145	431	6
55	805	777	139	412	5
56	827	830	132	392	4
57	848	883	126	373	3
58	870	935	119	353	2
59	891	.89988	113	334	1
60	.66913	.90040	1.1106	.74314	0
	cos	cot	tan	sin	'

49° READ UP 48°

TRIGONOMETRIC FUNCTIONS

42° READ DOWN 43°

42°

′	sin	tan	cot	cos	
0	.66913	.90040	1.1106	.74314	60
1	935	093	100	295	59
2	956	146	093	276	58
3	978	199	087	256	57
4	.66999	251	080	237	56
5	.67021	304	074	217	55
6	043	357	067	198	54
7	064	410	061	178	53
8	086	463	1.1054	.74159	52
9	107	.90516	048	139	51
10	129	569	041	120	50
11	151	621	035	100	49
12	172	674	028	080	48
13	.67194	727	022	061	47
14	215	781	016	041	46
15	237	834	009	022	45
16	258	887	1.1003	.74002	44
17	280	940	1.0996	.73983	43
18	301	.90993	990	963	42
19	323	.91046	983	944	41
20	.67344	099	977	924	40
21	366	153	971	904	39
22	387	206	964	885	38
23	409	259	958	865	37
24	430	313	951	846	36
25	452	366	1.0945	.73826	35
26	473	419	939	806	34
27	495	473	932	787	33
28	.67516	.91526	926	767	32
29	538	580	919	747	31
30	559	633	913	728	30
31	580	687	907	708	29
32	602	740	900	688	28
33	623	794	894	669	27
34	645	847	1.0888	.73649	26
35	.67666	901	881	629	25
36	688	.91955	875	610	24
37	709	.92008	869	590	23
38	730	062	862	570	22
39	752	116	856	551	21
40	773	170	850	531	20
41	795	224	843	511	19
42	816	277	1.0837	.73491	18
43	.67837	331	831	472	17
44	859	385	824	452	16
45	880	439	818	432	15
46	901	.92493	812	413	14
47	923	547	805	393	13
48	944	601	799	373	12
49	965	655	793	353	11
50	.67987	709	786	333	10
51	.68008	763	1.0780	.73314	9
52	029	817	774	294	8
53	051	872	768	274	7
54	072	926	761	254	6
55	093	.92980	755	234	5
56	115	.93034	749	215	4
57	136	088	742	195	3
58	157	143	736	175	2
59	179	197	730	155	1
60	.68200	.93252	1.0724	.73135	0
	cos	cot	tan	sin	′

47°

43°

′	sin	tan	cot	cos	
0	.68200	.93252	1.0724	.73135	60
1	221	306	717	116	59
2	242	360	711	096	58
3	264	415	705	076	57
4	285	469	699	056	56
5	306	524	692	036	55
6	327	.93578	686	.73016	54
7	349	633	680	.72996	53
8	370	688	674	976	52
9	.68391	742	668	957	51
10	412	797	1.0661	937	50
11	434	852	655	917	49
12	455	906	649	897	48
13	476	.93961	643	877	47
14	497	.94016	637	857	46
15	518	071	630	.72837	45
16	539	125	624	817	44
17	561	180	618	797	43
18	.68582	235	612	777	42
19	603	290	606	757	41
20	624	345	1.0599	737	40
21	645	400	593	717	39
22	666	455	587	697	38
23	688	.94510	581	.72677	37
24	709	565	575	657	36
25	730	620	569	637	35
26	751	676	562	617	34
27	.68772	731	556	597	33
28	793	786	550	577	32
29	814	841	544	557	31
30	835	896	1.0538	537	30
31	857	.94952	532	517	29
32	878	.95007	526	.72497	28
33	899	062	519	477	27
34	920	118	513	457	26
35	941	173	507	437	25
36	962	229	501	417	24
37	.68983	284	495	397	23
38	.69004	340	489	377	22
39	025	395	483	357	21
40	046	451	1.0477	337	20
41	067	.95506	470	.72317	19
42	088	562	464	297	18
43	109	618	458	277	17
44	130	673	452	257	16
45	.69151	729	446	236	15
46	172	785	440	216	14
47	193	841	434	196	13
48	214	897	428	.72176	12
49	235	.95952	422	156	11
50	256	.96008	1.0416	136	10
51	277	064	410	116	9
52	.69298	120	404	095	8
53	319	176	398	075	7
54	340	232	392	055	6
55	361	288	385	035	5
56	382	344	379	.72015	4
57	403	400	373	.71995	3
58	424	457	367	974	2
59	445	513	361	954	1
60	.69466	.96569	1.0355	.71934	0
	cos	cot	tan	sin	′

46°

47° READ UP 46°

TRIGONOMETRIC FUNCTIONS

44° **READ DOWN** **44°**

′	sin	tan	cot	cos		′	sin	tan	cot	cos	
0	.69466	.96569	1.0355	.71934	**60**	**30**	091	270	1.0176	325	**30**
1	487	625	349	914	59	31	112	327	170	305	29
2	508	681	343	894	58	32	132	384	164	284	28
3	529	738	337	873	57	33	153	441	158	264	27
4	549	794	331	853	56	34	.70174	.98499	152	243	26
5	570	850	325	833	55	35	195	556	147	223	25
6	591	907	319	813	54	36	215	613	141	.71203	24
7	.69612	.96963	313	792	53	37	236	671	135	182	23
8	633	.97020	307	772	52	38	257	728	129	162	22
9	654	076	301	.71752	51	39	277	786	123	141	21
10	675	133	1.0295	732	**50**	**40**	298	843	1.0117	121	**20**
11	696	189	289	711	49	41	319	901	111	100	19
12	717	246	283	691	48	42	.70339	.98958	105	080	18
13	737	302	277	671	47	43	360	.99016	099	059	17
14	758	359	271	650	46	44	381	073	094	039	16
15	779	416	265	630	45	45	401	131	088	.71019	15
16	.69800	.97472	259	610	44	46	422	189	082	.70998	14
17	821	529	253	590	43	47	443	247	076	978	13
18	842	586	247	.71569	42	48	463	304	070	957	12
19	862	643	241	549	41	49	484	362	064	937	11
20	883	700	1.0235	529	**40**	**50**	505	420	1.0058	916	**10**
21	904	756	230	508	39	51	.70525	.99478	052	896	9
22	925	813	224	488	38	52	546	536	047	875	8
23	946	870	218	468	37	53	567	594	041	.70855	7
24	966	927	212	447	36	54	587	652	035	834	6
25	.69987	.97984	206	427	35	55	608	710	029	813	5
26	.70008	.98041	200	407	34	56	628	768	023	793	4
27	029	098	194	.71386	33	57	649	826	017	772	3
28	049	155	188	366	32	58	670	884	012	752	2
29	070	213	182	345	31	59	690	.99942	006	731	1
30	091	270	1.0176	325	**30**	**60**	.70711	1.0000	1.0000	.70711	**0**
	cos	cot	tan	sin	′		cos	cot	tan	sin	′

45° **READ UP** **45°**

LOGARITHM TABLES

No.	Log.	No.	Log.	No.	Log.	No.	Log.	No.	Log.
1	0.000000	21	1.322219	41	1.612784	61	1.785330	81	1.908485
2	0.301030	22	1.342423	42	1.623249	62	1.792392	82	1.913814
3	0.477121	23	1.361728	43	1.633468	63	1.799341	83	1.919078
4	0.602060	24	1.380211	44	1.643453	64	1.806180	84	1.924279
5	0.698970	25	1.397940	45	1.653213	65	1.812913	85	1.929419
6	0.778151	26	1.414973	46	1.662758	66	1.819544	86	1.934498
7	0.845098	27	1.431364	47	1.672098	67	1.826075	87	1.939519
8	0.903090	28	1.447158	48	1.681241	68	1.832509	88	1.944483
9	0.954243	29	1.462398	49	1.690196	69	1.838849	89	1.949390
10	1.000000	30	1.477121	50	1.698970	70	1.845098	90	1.954243
11	1.041393	31	1.491362	51	1.707570	71	1.851258	91	1.959041
12	1.079181	32	1.505150	52	1.716003	72	1.857332	92	1.963788
13	1.113943	33	1.518514	53	1.724276	73	1.863323	93	1.968483
14	1.146128	34	1.531479	54	1.732394	74	1.869232	94	1.973128
15	1.176091	35	1.544068	55	1.740363	75	1.875061	95	1.977724
16	1.204120	36	1.556303	56	1.748188	76	1.880814	96	1.982271
17	1.230449	37	1.568202	57	1.755875	77	1.886491	97	1.986772
18	1.255273	38	1.579784	58	1.763428	78	1.892095	98	1.991226
19	1.278754	39	1.591065	59	1.770852	79	1.897627	99	1.995635
20	1.301030	40	1.602060	60	1.778151	80	1.903090	100	2.000000

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